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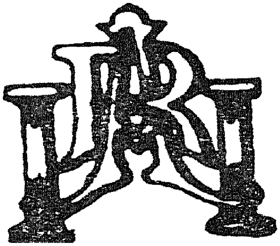

FAMINE ON THE WIND

Famine on the Wind

Plant Diseases and Human History

G. L. CAREFOOT and E. R. SPROTT

With a foreword by
SIR JULIAN HUXLEY

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To those who come after and do better

PREFACE

This book is about some of the important fungus diseases and a few of the viruses that have profoundly influenced the history of many countries of the world. All but three of the chapters concern plant diseases that have affected and still affect basic foods. The subject seems to be especially topical in view of the food and population problem that is just beginning to become acute.

We had other reasons for choosing this subject. Interest might be aroused in the public mind with the result that scientists could get the support they need in fighting plant diseases—and "fighting" is the right word because the diseases fight back. Thus, food now wasted would be saved to help feed the hungry people of our overcrowded world.

Probably our most important reason for writing this book was that we ourselves became interested in plant diseases and the impact they have had on man's affairs. And the more we became involved, the more fascination the subject had for us. We hope that those who read the book will get as much pleasure reading it as we had writing it.

FOREWORD

by Sir Julian Huxley

Famine on the Wind is an important book. In simple language, it tells the story of how man's increasing demands for food and for other valuable vegetable products like rubber and timber have been frustrated by pests—tiny insects, fungi, bacteria and even tinier viruses—and by man himself, with his unwillingness to curb his own increase.

It includes a wealth of historical details on pest-caused famines, and their political and social effects (the presence of influential Irishmen like Mayor Daley or Robert Kennedy in the U.S.A. is the result of their ancestors having been forced to emigrate by the great potato famine in Ireland, caused by one of these plant-parasites), and tells the fascinating story of how some of the pests have been temporarily conquered, by poison or by breeding pest-resistant strains of their host plants; and also how some of these have been utilized, like smutty wheat in the manufacture of ginger-bread!

But it ends with the conclusion that man is his own worst enemy, by permitting himself to over-breed. Within a generation man will drown in his own numbers, and will ruin the productivity and the amenity of his own environment. While overcrowding will certainly breed more violence, and could lead to large-scale war.

Let us by all means fight the pests and avail ourselves of new sources of food like diatoms, however distasteful. Meanwhile the only remedy is world-wide birth-control: the question (very topical in the light of the Pope's Encyclical) is whether we shall achieve it in time to prevent world-wide famine and violent competition for the earth's dwindling resources.

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Prologue

POPULATION CRISIS

Every second, the world over, births exceed deaths by more than two. The first doubling of the world's population, starting from the time of Christ, took 1,650 years; the next came in 200 years; the third took only about 80 years, and the fourth doubling is expected to occur in less than 40 years. Because of this ever-shortening period, the most pessimistic demographers predict that the "saturation point" will come in little more than 60 years unless the food supply, natural or artificial or both, runs out first. Thus they forecast doomsday: the year 2026.

Obviously there are but two ways of meeting the minimum nutritional needs of future generations: more food must become available, and population must be controlled, and these twin problems must be dealt with immediately. The Food and Agricultural Organization of the United Nations, an organization not given to alarmist propaganda, states:

> Time is too precious to be wasted in futile arguments over what steps should be taken first to deal with the problem of population and food supply. Nothing less than an "all out" attack on all major aspects of the problem can bring success. To banish hunger and achieve a minimal diet for all people in the face of rapid population growth will take time. To check population growth in those countries where such is the desire of the people and their governments will also take time. *And time is of the essence.*

Many diseases that once kept the human population in check have been all but eradicated. Animal husbandry, hybridization, scientific soil management, and mechanization have dramatically increased food production in some parts of the world. Yet such heartening progress has not marked man's struggle against the many fungus diseases that annually destroy enough food to provide 2,500 calories per day for 300,000,000 people. This book tells about a few of these diseases, some of man's struggles to combat them, and some of the effects of these diseases on man and his history.

An adequate daily diet for adults varies according to their age, weight, and occupation. Generally, sedentary workers require 2,100 calories, those doing heavy labour, 3,500. A person receiving less than his required minimum is undernourished. Even an adequate number of calories cannot guarantee proper nourishment without sufficient vitamins, minerals, and high-quality proteins.

Demographers—the statisticians who keep track of human affairs like births, deaths, area densities, and so on—offer differing forecasts. The population of the world today is approximately three thousand million. Optimistic demographers predict that since men and women are rational beings, they will see the danger of bringing children into a world where the predictable daily diet will be less than 2,000 calories. Thus voluntary control will help to check the accelerating upswing in population and, these optimists believe, the world population will level off before the five thousand million mark is reached. More pessimistic demographers fear the rate of increase will continue until the population doubles every twenty years.

If the pessimists are right, in eighty years the population of the world will be fifty thousand million. Distributed uniformly over the earth's total area, this means 800 people per square mile on ice-covered Greenland and Antarctica, in the Sahara, Arabian, and Gobi deserts, and even on the sides and peaks of the Rocky Mountains. Obviously, since these places are uninhabitable, today's most densely populated areas will simply become more burdened with people. Even if the scientists, agriculturists, and hydraulic engineers could double the amount of arable land, each food-growing acre then would have to feed seven people, the ratio of arable land to people in Japan today.

To meet their present needs, the energetic Japanese must scour the Pacific, from the shores of Korea to those of Canada and from the rocky islands of the Bering Sea to the coral atolls of the South Pacific, with their modern fishing fleets. Where one acre of rice can adequately feed but four people, the hard-working farmers fail to raise enough rice and soya beans to meet their country's annual protein needs by millions of metric tons. Famine would strike half the people—not years from now, but now—if the nation could not import foodstuffs.

If the time comes when each acre of farm land on the earth's surface must feed seven people—and it could happen within the lifetime of babies born today—it will be doomsday, the time of reckoning.

Meanwhile, the net increase in the earth's population is 7,500 per hour, 180,000 per day, 66,000,000 per year. Over a three-year period this increase equals the 1963 population of the United States; over a seven-year period, the present population of India; and over an eleven-year period, that of China.

Why is the human population multiplying so rapidly?

One reason is that medical researchers and practitioners have been able to postpone death for almost every individual by decades. Malaria still kills approximately two million people every year, but its toll has been greatly reduced by proper health measures. Infant mortality and deaths from all childhood diseases have been reduced drastically. Many diseases that once cut down countless men and women in their prime are now, like pneumonia, no longer dreaded words in our vocabulary, thanks to the modern achievements of medicine. The most effective panacea for mankind's diseases has been the antibiotics. These drugs, along with new insecticides, have rid wide areas of the earth of recurring epidemics and plagues. The average death rate, therefore, is down to its lowest recorded level.

Another reason for this frightening population growth is that the birth rate in most countries since World War II has not dropped to parallel the death rate. The number of births per thousand has not even levelled off. Instead, in most countries—poor or rich, dependent or free, backward or advanced—the birth rate has accelerated, and the population has either doubled or is in the process of doubling.

By a rough rule of thumb derived from the one used in figuring compound interest invested, the number of years it will take a population to double can be calculated, taking the number by which births exceed deaths and expressing it as a percentage of the total population, then dividing the result into the number 72. For example, since the excess of births over deaths in Mexico is 3 per cent of the total population of that country, the Mexican government should plan for the feeding of twice the present forty million mouths in twenty-four years

—72 divided by 3. The same calculation applied to North Americans above the Rio Grande shows their population doubling in about 40 years, and they might have some nutritional problems of their own.

The consequences of doubling the world's population to six thousand million in 35 years are impossible to foresee. Until now, man has had but four main checks on his numbers—war, disease, famine, and himself. In the latter half of this century, working through the world parliament of the United Nations, he has managed to minimize international conflicts. Through the remarkable progress of medical science, he has all but eliminated disease as a mass destroyer. Improved communications and transportation facilities have greatly expedited the movement of food to areas of need. Formerly, for example, if famine occurred in the northwest provinces of India, weeks passed before word filtered to the rice producing plains of the Ganges delta, and then it often took months for ox carts to carry relief to the starving frontier people. Nowadays, the central government in Delhi can deliver food, if food is available, to such stricken areas in days or even hours.

The responsibility for checking population lies squarely with man himself. If he fails to apply voluntary methods to halt the current increase, he will run into that barrier he has so far been able to avoid: universal famine.

The demographers whose calculations provide informative guideposts for the use of planners and legislators, can so far point to only two countries that seem to have learned how to control runaway fecundity. One is Ireland and the other is Japan. The Irish learned from experience what overpopulation can mean to a people. Famine, disease, and death came to Ireland five generations ago when a plant disease attacked their staple food, and the Irish have never forgotten. Their birth rate since then seems to have been curbed by the relatively painless methods of stricter supervision of the young by both family and church, late marriages, family planning—and a bit of "Irish luck".

On a group of islands halfway around the world, the Japanese, twenty-five times as numerous as the Irish, are trying to maintain themselves in a mountainous country less than five times the size of Ireland. In ten years, by drastic methods—including legalized, government-sponsored abortion—the Japanese have reduced the birth rate so sharply that a balanced population could be achieved within the next ten years. Even so, the population pressure by that time will be almost intolerable, averaging 800 people per square mile, and the country will be in a tragic condition unless it can continue to import adequate quantities of foodstuffs.

Nevertheless, the Japanese achievement in controlling its birth rate by abortion and contraception is spectacular and hopeful. There is doubt, though, that other people of the world will soon accept abortion as a population check since the idea of terminating the life of a human foetus is either distasteful or psychologically and religiously unacceptable to most peoples at the present time.

Why were the Japanese receptive to this almost universally tabooed method? Perhaps the tradition began 250 years ago when the Japanese lived under the dictatorial shogunate which enforced population control. In those harsh years, Japanese parents came to accept stoically the annual human "Mabiki"—thinning of the crop. The usual method then used to control the population was abortion, but often the shoguns ordered infanticide.

Although the Japanese have twice in their history proved that legalized abortion works, probably the world's governments will not seriously consider this method of population control until long after the propitious time has passed. In fact, many experts contend the optimum balance between population and natural resources has already been passed, even in North America, several millions-of-people ago.

During the first half of the twentieth century, most countries of Europe maintained a relatively low birth rate because of economic and social pressures. There was also considerable emigration, which is a form of population control, from the "old countries", and two of the most savage wars in history further thinned the peoples of Europe. Nevertheless, despite relatively stable numbers, the Western Europeans could not feed themselves, but had to import many millions of tons of foodstuffs. Of course, they had to export at least enough manufactured goods to pay for the needed food. Precarious as this state of the economy was, actual hunger never threatened except when the delicate import-export balance was upset by war.

By 1940, the birth rate in most European countries was so low that demographers expected the population to become stable. The rate of increase in Britain was particularly low. By 1955 it was lower than that of France, and the demographers were predicting that in 1960 there would be only about 600,000 births. Instead, 800,000 babies arrived, and this trend has continued. It is likely that by A.D. 2000 Britain will have to increase its food imports to feed a population of 80 million.

On the west side of the Atlantic, the postwar baby crop was a bumper one, too. Then, in 1963, the population of the United States increased by more than three million, or 1.5 per cent, due to births alone. Moreover, both the Canadian and American governments are still accepting and even encouraging immigration. This policy will probably continue until the alarming numbers of unemployed compel governmental curbs. Otherwise, it seems certain that when Halley's Comet comes again in 1986, three hundred million pairs of bright—and perhaps hungry—eyes north of the Rio Grande will be searching the clear night skies.

Some minority groups, probably through fear of losing their cultural identities, reproduce at a faster rate than the average. In the United States and Canada such groups include the Hutterites, Puerto Ricans, Mexicans, and French Canadians. The French Canadians, for example, increased between 1650 and 1950 from six thousand to eight million, and to twelve million if those of French Canadian descent now living in the United States are included.

As these minorities begin to exert economic pressure they are often regarded with suspicion, or even with genuine dislike, particularly if they speak a different language or are marked by different physical characteristics or social mores. Already, in the Province of Alberta, legislated restrictions have been placed on the Hutterites. Nevertheless, such groups often maintain or enhance their position in relation to their more secure neighbours by a successful "battle of the cradle".

One important reason the birth rate is not falling enough to compensate for the falling death rate is that man, for all his intellectual attainments and social development, is an animal species subject to natural laws. In all species, whenever many dangers threaten the individual in the interval between fertilized egg and adulthood, the response is to procreate large numbers of offspring. That is why rabbits have more progeny than their predators, the coyotes. And man responds to peril in a similar way. Fecundity rises in times of war and other peril because of the feeling of danger to the race.

Scientists have found that once a species diminishes in numbers, the chances of rebuilding the population are poor, even when utmost aid and protection are given. Apparently the diminished pool of "good" genes makes for greater spreading of "bad" genes in the small group, lessening the viability of the average member of the group. This theory helps to explain why a species, seeming to fear anything that may reduce its numbers, reacts vigorously to produce a large number of offspring. However, some species, having suffered catastrophes from which they could not recover, have become extinct or almost extinct. The number of whooping cranes, for example, may already have been reduced below that species' survival point. All vigorous species, including man, strive to avoid this danger by reproducing abundantly in times of peril.

Hunger is one peril, and birth rates always begin to rise as food becomes scarce. The rise in fecundity may develop because of the lack of protein, the organism's basic material in building the new protoplasm needed for replacement of worn-out cells. Without the amino-acids in protein, the body tissues waste away. Perhaps this protein hunger in Eastern countries where diets are deficient in protein is one reason why the fertility of the people is high even in good times.

Now, in this era of hydrogen bombs, with savage snarling between the great powers of the earth, the threat of war, and the ever-present dangers of radio-active fallout from test bombs, mankind is reacting by maintaining a high birth rate in spite of better information and more effective techniques of birth control.

In 1961, a group of Nobel prizewinners and other prominent persons petitioned the United Nations to give the peoples of the world real leadership in promoting worldwide programmes of birth control. But in this vital matter the United Nations, at that time, took cover behind evasive words and tactics. Some of the member countries seemed to be too timid even to vote on the issue. Canada and Brazil, each with its own population explosion in its northeast section, were among the many nations that abstained. Behind the political scene, though, U.N. organizations keep planning and working to foster a more realistic attitude towards this pressing problem.

Some governments, that of India for example, have recently acknowledged their own population and food problems. Contraceptive methods and family planning are being promoted vigorously. Nevertheless, the annual increase in the population of the world rose from sixty million in 1961 to sixty-six million in 1965, and the demographers have little hope that this yearly increase will decline during the remainder of the twentieth century.

The vital question now is not how many persons there are per square mile, but how many square meals per person are available. What is the actual ratio today between available food calories and the world's three thousand million people? According to the Food and Agriculture Organization of the United Nations, it is about 2,400 calories to one person. Averages, however, do not tell the story. While persons in the "have" countries now enjoy a diet averaging 3,060 calories, an increase of 150 calories over the 1940 level, those in the "have not" countries must make do with 2,150 calories, an increase of only 20 calories since 1940. In fact, two thousand million people in the overpopulated countries are still confronting malnutrition, despite slight gains.

Some submarginal land in Asia has come into agricultural use. Greater use of fertilizers, more irrigation, larger yields, improved machinery, more available power, and better farming practices have resulted in larger harvests. In some fortunate countries, such as the United States, agricultural productivity has risen a full 50 per cent since 1940. Nevertheless, the vital supply of proteins in the food of the world's people has dropped an alarming 8 per cent from 1940 standards.

The population's rise in the past twenty-five year period has had at least one other direct, adverse effect on American and Canadian crop potential: in the urban sprawl around the cities and in the super highways connecting those cities, 7 per cent of the rich agricultural land of the United States has been covered with concrete and blacktop and houses! So far, no planning boards have succeeded in restricting residential areas to non-agricultural land; and highway building in a single year, 1960, consumed a quarter of a million acres of arable land and an equal amount of pasture land in Canada and the United States. Such prodigal waste of food-producing land may prove disastrous in years to come.

1 Purple Cockspurs and LSD

ERGOT OF RYE

Dr. Jean Vieu glanced at the calendar—August 12, 1951. He then looked out his office window across the swirling grey water of the swollen Rhône lapping at the solid abutments of the ancient stone bridge in the little town of Pont-St.-Esprit in Provence. Southern France had not been very sunny that year of 1951. Never had there been so many dull and rainy days.

The doctor was puzzled. He had just returned from making a professional call. At first he had thought it was another case of acute appendicitis, for the patient complained of intense pain in the lower abdomen and tension in the abdominal wall. But there were none of the other usual symptoms; no rigidity on the right side or instinctive flexing of the right knee. Instead of the usual fever, there was a low body temperature and cold fingertips. The strangest symptom of all had been a wild babbling, not like delirium, but more like the hallucinations of true dementia.

The doctor had two similar calls that day and one early on Sunday morning, August 13. He phoned a colleague, and what he heard was so disquieting that he immediately got in touch with the third doctor of the town. The three had a brief meeting that evening. Altogether they had almost twenty cases of the strange malady to treat. That it was an epidemic of food poisoning they were certain, and at first they suspected the meat supplies of the town.

The calls from stricken new patients kept flooding in. By Monday, August 14, the town's hospital was swamped. Seventy homes had also been turned into emergency wards. That night the first victim died in agonizing convulsions. Raving patients were held in their beds or escaped from their homes, mad, frantic, to run in the streets. The terror grew as the news broke that a demented eleven-year old boy had tried to strangle his own mother. The mood of the people and the atmosphere of the place began to resemble that of a plague-swept town of the Middle Ages.

The three doctors of Pont-St.-Esprit acted quickly, persuading the mayor to institute a house-to-house search for clues. It was not long before the investigation uncovered a common element: all the patients had eaten bread from the same baker. Samples of this wheaten bread found in the homes and in the bakehouse were sent to Marseilles for analysis.

Meanwhile, the people and their doctors did what they could to relieve the sufferers. Dozens of straitjackets were rushed into the town, for the sick had to be forcibly restrained to prevent attempts at suicide. The doctors were harassed, overworked, and worried about the pall of fear and superstition that had settled over Pont-St.-Esprit. Some villagers suspected provincial authorities of inflicting mass poisoning for obscure political reasons; others accused the village idiot of having bewitched the baker.

Finally, the chief toxicologist of Marseilles sent his report to Pont-St.-Esprit and the anxious nation. The bread contained twenty alkaloid poisons, three of them virulent, and all came from the same source. The poisons could be found in a fungus growth that changed normal kernels of rye to purplish cockspurs called ergot.

The doctors were relieved by the news, at least relieved of their fears, that this might be a new and terrible plague. The authorities redoubled their efforts to unravel the strange case. How had a poison that was historically associated with rye bread got into the wheat flour baked in Pont-St.-Esprit?

At last, and after some weeks, the sordid tale unfolded. A miller three hundred kilometres away, beyond the Auvergne Mountains on the wheat-growing plains of north central France, had ground the flour. An unscrupulous farmer of that region had sold his polluted rye grain to the local baker. The baker had delivered it to the miller. The miller had mixed this poisonous rye with wheat and ground the mixture into flour which he shipped far away to Pont-St.-Esprit in the valley of the Rhône where he was not known. All three—the farmer, the baker, and the miller—knew the rye to be poisonous.

In the autumn of 1951, these three wicked men, to avoid paying twenty francs per kilo sales tax, distributed the poisonous rye responsible for over two hundred cases of severe and damaging illness, thirty-two cases of insanity, and four deaths.

The news of the outbreak of ergotism in France in 1951 was startling indeed, for in the modern civilized world an ancient disease seldom gets the upper hand over medical science for even a few days. But it was different in the Middle Ages when ergotism was a dreaded and common sickness. The "Holy Fire", or "Heilige Feuer" as the Germans called the disease, had ravaged man and his livestock as far back in time as man's memory could grope, not only in France and Germany, but in all of Europe. The mere words, Holy Fire, struck the hearts of the peasants with a dread a thousand times worse than the awful word, cancer, inspires in people's minds nowadays. The suffering caused by Holy Fire tore away men's reason and turned them into screaming, gibbering brutes, or into hopeless cripples as their fingers, toes, arms, and legs blackened and corroded from a dry gangrene. Each sufferer, always and without fail, won surcease from his pain only by death.

This disease raged throughout all Europe in the Middle Ages, consuming the minds and bodies of countless men, women, and children. But in 1670 a quiet, patient man, favoured by keen observation and logic, found its cause.

Dr. Thuillier, a French country physician, was well acquainted with the symptoms of Holy Fire. He saw dozens, even hundreds, of his patients slowly destroyed by the disease, screaming and jerking in their fatal convulsions, and all Dr. Thuillier could do was tie them to their beds until death wiped out their horrible visions. He did what he could to ease their pain; he watched and wondered.

Three curious facts about Holy Fire slowly became clear as he treated the sick. First, the disease was not infectious. Some members of a family caught the disease, but others did not. Some families were wiped out by it, but their neighbours escaped. Some individuals, even though they were isolated from others for months, caught it. Dr. Thuillier concluded that it was not like the Black Death or like smallpox, the Red Plague.

Second, the scourge swept through the rural districts of France with great loss of life, but the people living in the cities were little affected by it. Most other plagues, the doctor knew, struck down the people in the crowded cities but scarcely touched the isolated peasant farmers.

The third fact Dr. Thuillier noted was the most curious of all. It seemed as if resistance to the Holy Fire could be bought with money. It was a disease of the poor; the rich folk escaped it. If the disease was not contagious, the doctor thought, the trouble must come from the sufferer's environment. But how could the clean air, the fresh breezes, the warm sun of the countryside strike down the innocent and God-fearing peasants, while the foul air and the dirt of the cities left the roisterers, the roués, and the bravos unpunished for their sins? Dr. Thuillier was convinced that the air of the countryside had nothing to do with the disease.

Perhaps the secret lay in what the people drank or ate? The doctor knew that the country folk drank water and good red wine, as did the city folk. He knew also that farmers ate the produce from the farms, and so did the city people.

On his visits to the sick, he looked at what was set on the table. Sometimes there was fat pork, sometimes beans or peas; but always the main staple was in the middle of the table, the big loaf of rye bread, heavy and filling. A few villagers ate the new-fangled *pommes de terre*, the potatoes the Spaniards had found and brought back from the New World a century before. Many of the others, the more superstitious ones, would not even grow potatoes on their land. Could potatoes be the cause? Dr. Thuillier was suspicious of potatoes himself for a time, but when he read of the old days and listened to the stories of the *grand-pères*, he had to admit that Holy Fire had plagued the people of France and Spain, too, for hundreds of years before potatoes came to the peasants' tables.

Dr. Thuillier watched the peasants drive their fat cattle, their sheep, their geese into the cities to be sold along with their golden wheat in the marketplaces. That was what the city people ate—rich beef, fat poultry, truffles, and white bread.

Somewhere there had to be an answer.

The doctor became obsessed in his search. In his leisure time he walked the country roads; he wandered through the peaceful fields. He talked, he asked, he pried, and always he turned over in his mind the things he had observed. But the more he strove to find the cause of Holy Fire, the further he seemed to be from the answer.

Then one day it came. He saw something in a rye field, and a flash of insight illuminated the whole problem. The answer had been before his eyes countless times, but he had not seen it, there, in those heads of rye swaying under their heavy loads. Dr. Thuillier took one in his hand. There, swollen and purple and crowding out the healthy rye kernels, hung five great cockspurs or ergots, as the French called them. And Dr. Thuillier knew that in his hand lay the cause of the burning scourge of his people. He looked about and saw them, thousands upon thousands of great purple spurs, protruding from the countless yellow, ripening heads of rye in that field.

Dr. Thuillier knew of these ergots. He had read that even the old alchemists had used them in their potions. The ground-up ergots were said to hasten childbirth. Perhaps they could be used as a medicine, but he knew that powerful medicines must be administered in small doses. Larger portions of even the best medicines could be poisonous. Here was the answer—that great heavy loaf of rye bread lying on the farmer's table at every meal. The good peasants, ignorant of the danger, were eating bread made from ergoty rye flour.

A little more patient inquiry and a look at his records was all that Dr. Thuillier needed to be positive that he was right. In the bad years, years when the rye heads were blackened by ergot, Holy Fire raged through the countryside and people died by the hundreds. There was the proof!

The doctor was sure he had found the secret to a great and terrible mystery, but he could not convince the stubborn farmers. They did not believe that rye bread could be a poison. He needed more proof, but he was never able to get it. Two hundred years and many researchers later, in 1853, Louis René Tulasne peered at the ergots through the microscope, studied the growing rye and its inconspicuous flowers, did numerous experiments, and came up with the irrefutable answer.

The criminal was certainly not the rye itself, but a fungus parasite of the grain. This fungus has been called *Claviceps purpurea*, for *Claviceps* means "club-headed" and *purpurea* is Latin for purple. It can and does attack many other grains and grasses, but its favourite host is rye.

The ergot fungus has a yearly cycle that really has no beginning and no end, but goes through time in an infinite spiral. The hard, purple sclerotium among the ripening rye grain is the over-wintering state of the fungus and is not meant to be eaten by man or beast. In fact, the presence of the poison it contains is a built-in protection against that fate. The fungus produces its ergot to get through the hard, cold winter. If it falls from the rye head, the fungus can stand the frosts and the snows. Even if the ergot is trampled below the surface of the soil, it is safe from harm as long as it is not buried too deeply. The fungus rests there dormant and alive until the spring sun warms the earth again.

In spring, the purple ergot, moistened and warmed, germinates and produces several slender stalks in pale shades of red through mauve. Each of these stalks, or stipes, bears at its tip a pink, or fawn-coloured globe. These germinating structures look remarkably like small twisted mushrooms. In the surface of these tiny heads are hundreds of still smaller receptacles, and in each of these are scores of microscopic sacs or asci. Thousands upon thousands of ascospores are ejected from the asci into rising air currents. They float on the spring winds to the young and tender rye plants. When one considers that these hairlike ascospores are ejected to heights that range from 150 to 500 times their own length, one can realize the great relative force generated in the saclike "blowguns" of the ergot.

The odds against one of these spores infecting a rye flower are millions to one, for the spore must come to rest first on a receptive flower. Second, it must lodge near the base of the ovary, and that is a small target indeed. It would probably be much easier for a blindfolded archer to hit a fly in the eye at five hundred yards.

Once it has entry, however, the fungus uses a simple but devilishly effective way to enlist the aid of countless allies. Its primary mycelium, the mass of matted threads that make up the body of a fungus, produces a sweet honeydew full of millions of a different kind of spore, conidiospores. This sweet exudation attracts swarms of insects, most of them flies; but beetles are attracted, too. After feeding on the mixture of honeydew and spores, and with the sticky fluid on their legs, these insects flit from rye flower to rye flower searching for more. The honey spores that are spread to the healthy flowers then germinate and infect the rye blossoms. Thus, the disease spores are disseminated by the insects and by the fine drops of water in heavy spring fogs. It is easy to tell if the fog carries ergot spores because the ascospores in moist air are surprisingly bad smelling.

When these conditions prevail, the fungus spreads explosively through the fields, until in some bad-ergot years half or more of the rye heads are blighted. For some unknown reason, all of the infected flowers do not produce ergots. However, in those heads where the fungus does flourish, the great purple cockspurs grow and harden.

These ergots are either flailed by the blustery autumn winds or are harvested by the farmer, and so the annual cycle of the ergot is completed. Today, with this knowledge so slowly and painstakingly obtained, the ergot fungus is not difficult to control. First, the rye farmer must sow ergot-free seed. Screening the seed grain will remove only a fraction of the ergots. To clean the rye seed more thoroughly, a flotation process is used. Long ago farmers found that if ergoty rye were put into a brine of about 30 per cent common salt and stirred about, the sclerotia or ergots would float and could be skimmed off. More recently, however, potassium chloride has been substituted for salt because there is less damage to the seeds, and the solution can be used later as a fertilizer. After the flotation process, the cleansed rye seed is dried and planted.

Second, deep autumn ploughing will bury residual ergots lying on the ground so deeply that they will never germinate. A crop rotation scheme in which a non-susceptible crop is planted on alternate years is a sensible practice offering a third defence.

That is about all that man has been able to do. The sad truth is that no one has yet found a single rye plant in the whole world that is resistant to ergot. Therefore, the plant breeders have no material to work with, and so no rye that is resistant to the ergot fungus can be developed.

One last precaution against ergotism is taken in all civilized countries. The percentage of ergot allowable in rye flour is controlled by government laws or regulations. By the careful observance of safeguards for rye flour purity, man has freed himself from the scourge of Holy Fire.

The history of ergotism is very sketchy, leaving large gaps in our knowledge. No mention is made of the disease in the writings of the ancient civilizations bordering the Mediterranean, of the Fertile Crescent, or of the East. But surely a human disease with such startling symptoms and devastating results would have come to the attention of the learned men of ancient times.

Since ergot is primarily a disease of rye, then rye must have been unknown to the ancient farmers. Spelt, which is an ancient kind of wheat still cultivated in parts of Europe, and barley, rice, wheat, and oats were known and grown because those grains seem to have had their origin along the southern fringe of the North Temperate Zone. From where did rye come? Apparently man found this last of the great grain crops somewhere north of the Aral or Caspian seas, where wild rye was grown by the semi-nomadic Franks and Vandals who wandered to and fro between eastern Russia and western Siberia, far from the centres of civilization, for centuries before Christ's birth. Little or no contact occurred between these nomadic peoples and the great civilizations far to the south until near the end of the Roman Empire. Doubtless the Franks and Vandals carried rye grain in their saddle pouches as a provision while riding on their wild forays into the disintegrating Roman Empire. Rye, therefore, was virtually unknown to the civilized farmers until the beginning of the Christian era. The first mention of any human disease remotely resembling ergotism was made by Pliny the Younger who wrote in the second century A.D., and we cannot be sure from what he reported whether ergot of rye caused the disease.

The first reports of outbreaks of Holy Fire came from the kingdom of the Franks during the eighth and ninth centuries, and ergotism became the special curse of the French for the next eight hundred years. The Romans and the Greeks had known of this new grain from the lands beyond the Black and Caspian seas, but rye never became popular with them or their descendants. Perhaps because of the nature of the French soil, the climate, or the hardiness of the plant itself, rye did become a popular staple grain in France. The people developed a liking for the black rye bread, and that bread was the main item of diet for the mass of French peasants.

The first serious epidemic of ergotism was recorded in A.D. 857 in the Rhine valley. The plague struck thousands of peasants with its loathsome symptoms, and people died by the thousands. That was when the disease came to be called in Latin *sacer ignis*, the sacred or Holy Fire.

In that period, the hundred years between A.D. 800 and 900, France suffered another scourge. This was a human one, and it came by sea. There had developed in Scandinavia a race of people the like of which the world had not yet known. Huge, daring, energetic, and cunning, these warrior adventurers drove their longboats before the scudding winds of the North Sea onto the shores of France. The tocsins rang the warning: "The Northmen, the Northmen". But the Franks along the coasts were no match for the raiders, and no effective help came from the dukes of France. Before A.D. 900 the Northmen had settled permanently on the northwest coast of France and had begun to exert pressure on the Holy Roman Empire formed from the great kingdom of the Franks by Pope Leo III. The Northmen were so successful in their raiding that Charles the Third was forced to abdicate the throne of the Holy Roman Empire in 887. So much ill feeling resulted from the abdication of Charles and the successes of the Northmen that the Empire split permanently into two kingdoms. The kingdom of the West Franks became France and the kingdom of the East Franks became Germany.

Ergotism did not greatly affect the Northmen in France for two reasons. Rye was not a staple food of these Viking raiders. Second, the fungus found ecological conditions better for its growth in the dukedoms of France lying to the east and the south of the Northmen's settlements.

In 911 the Northmen's hold on the northwest coast of France was complete, and the king of France ceded to them the territory that later became known as Normandy. Doubtless the vigorous Normans would have extended their rule over the feudal domains of France lying to the east and the south of Normandy but for the intense interest that William, Duke of Normandy, developed in the affairs of the island kingdom that lay across the narrow channel.

How much the Northmen's success depended on their own vigour and sagacity and how much was due to the decimating holocausts of Holy Fire on the population of France can never be ascertained. But one fact is certain: a sick people cannot fight a race of hardy barbarians. The Normans established themselves firmly in conquered Normandy, an area small in size but great in the influence it has had on the world.

Although ergotism brought much agony and suffering to mankind, it had one good effect. In 1039 another epidemic of the burning disease spread through France. The flames of that disaster, and of the epidemics that followed, kindled a different sort of fire in the heart of a godly man. Gaston de la Valloire, being a man of substance and full of pity for the victims of ergotism, built a hospital in the valley of the Rhone near Vienne and dedicated it to the relief of the sufferers. This hospital was dedicated to the memory of St. Anthony, and his sacred relics were kept there.

The *ardents*—the burning ones—were welcomed, and what little that could be done by the monks to ease the suffering of the sick was done. But whether the gangrenous cripples were helped by the kindness and prayers of the monks or whether they benefited from the absence of ergoty bread in their diet, we do not know; yet we do know that the Order of St. Anthony became known throughout Europe as the healers of those sick from the Fire, and that they set up over 390 hospitals in France. Each hospital was painted a symbolic red to remind the illiterate peasants from afar that they could get divine aid there to ease their torment. Gradually the old name, Holy Fire, was forgotten and the succeeding generations of sufferers called it by a new name, "St. Anthony's Fire".

Ergotism raged on, and the special hospitals were filled to overflowing in those terrible years of the eleventh and twelfth centuries when the disease blazed through the rye-farming valleys of western Europe. It was God's will, the devout said.

Rye did not become a popular field crop in Germany, Poland, or other parts of northern Europe until after the beginning of the sixteenth century. The first epidemic of ergotism occurred in Germany in 1581 when thousands of people in the Duchy of Luxembourg died. This outbreak took the convulsive form of the disease. Convulsive ergotism twists and arches the body as massive seizures in the muscles bring tearing and unbearable pain. There were sporadic outbreaks of the disease in France and Germany during the next century. The first verifiable cases of St. Anthony's Fire in Russia were reported in 1722.

Russia had but recently emerged as a modern European power after centuries as a wild, semi-oriental kingdom of squabbling dukedoms long regarded as an amusing and interesting but unimportant hinterland on the eastern fringes of European civilization. There had been little indication during the sixteenth and seventeenth centuries that the Russians were about to move into a position of equality with the other nations of Europe. True, the hold of the golden horde of Mongols on the boyars—the dukes of Russia—had been broken in 1554 by Ivan the Terrible, the first Czar of Russia. Ivan then broke the power of the boyars, in turn, and made himself supreme, but on his death Russia's affairs became chaotic.

There were no signs at all that wild young Peter, grandson of the first Romanov Czar, would ever become the chief builder of the Russian Empire. He was thrust into power as Czar of all the Russias at the age of seventeen. Peter drank too much, roved with wild companions, and was as dissolute as any young Russian prince had ever been. But, like the roistering Prince Hal of England who became the astute and resolute

Henry the Fifth, this muscular, six-foot-seven-inch giant became the best ruler Russia had ever had.

His grand dream of making "Mother Russia" a strong, modern power soon began to come true. By introducing Western ideas of technology, science, and government, he brought the Russians headlong into conflict with two powerful nations on Russia's borders. These nations, Sweden on the west and Turkey on the south, held what Peter Romanov ~~most desired~~—free access to the great oceans of the world. He saw clearly that Russia would always be a second-class power until ice-free ports were secured. When the great markets of the world could be reached cheaply and freely, Peter knew Russia then could close the gap between herself and the progressive nations of Western Europe.

In 1696, when he was twenty-three, Peter completed his first task, the founding of a Russian navy. With this instrument he seized the fortress of Azov from the Turks and gained access to the Black Sea. Then in 1700, Peter wheeled his armies against Sweden, who held the Baltic coast from Finland to Prussia. In twenty-one years of tenacious struggle, by good luck, increasing experience, and fortunate alliances, he forced Sweden to give up the eastern shore of the Baltic. Russia had pushed open her door to the West.

Now, strong in soldiers, arms, and military experience, Peter turned to the conquest of Turkey in order to gain the ice-free ports on the Black Sea.

compel

For centuries, the Turkish Sultan had held in subjugation the Ukrainians, Romanians, Hungarians, Serbs, Greeks, and the southern Slavs. The Muslim Turks treated their conquered subjects as human cattle; in all history no domination of one people over another, except that of outright slavery, has been so degrading. From Constantinople to London the Turks were feared and hated as the cruel and merciless infidel oppressors of the Christian peoples of southeastern Europe; Peter Romanov knew that the Sultan had no allies in Christendom.

Moreover, twice before Peter had tested the strength of the Sultan's armies. The first time was just before his war with Sweden and the second in 1710 when Charles of Sweden had fled into the Turkish Ukraine. Both these military probings had turned out advantageously for Peter, and had been just the right kind of military training that an emerging people needed before a fight to the death with a decadent but still powerful empire.

For another reason, and a most peculiar one, Peter had by chance chosen the most propitious moment to strike. Ahmed III, Sultan of the Turkish Empire, had appointed a learned man, Ibrahim Pasha, as his Grand Vizier. It so happened that this new Grand Vizier had a hobby which he passionately followed and taught to the other ranking officials in the Sultan's government. The hobby spread with an almost hysterical intensity to all the influential people in Constantinople, the heart of the empire. Everything else was neglected, subordinated to this new interest. And what was this all-absorbing craze? Growing tulips!

Constantinople and the Turkish Empire was in its tulip period when Peter began to gather his Cossack cavalry at Astrakhan. The time to strike had come. Swooping down the corridor of the Caucasus to the Asian heartland of the Turkish Empire, Peter was confident his cavalry would suck the European forces of the Sultan out of the Ukraine and the countries west of the Black Sea. Next, the Russian navy would sweep the Turkish ships from the Black Sea and through the Bosporus. Encouraged by the rout of their oppressors, the Ukrainians and the southern Slavs would swell the Czarist legions and help drive the Turks back into Asia from whence they had come centuries before. Then, ough the Sea of Marmora and the Dardanelles, trade would flow etween the Russian heartland and the rich markets on the shores of the Mediterranean and the western oceans. Russia would become the greatest nation of the world in the days to come!

So Peter the Great, in 1722, led his Cossacks to the great marshalling area at Astrakhan on the delta of the Volga, the place where the river emptied into the Caspian Sea. Like all armies of that period, the Russian army lived off the country, so when the Cossack cavalry galloped into Astrakhan, the serfs of the Volga delta came in with their carts loaded with rye, rye by the cartloads, rye hay and grain for the horses, heavy, filling, and nourishing rye flour for the men.

Then, one night in late August, 1722, the first horse went down with the blind staggers. Later, as the cock's crow broke the dawn's quiet, a weird shriek of a man in agony rang through the bivouacked troops. By noon that day over a hundred horses were down, their forelegs paralyzed. By the next evening, scores of maddened soldiers screamed and twisted in the tents and on the ground. It was the Holy Fire, the curse of God, visited upon the sinners of Mother Russia.

In all, twenty thousand people died that autumn in and about Astrakhan. And the strength of Peter the Great waned as the horrible, burning death tore, blackened, and withered the flower of Russia's military power.

It is impossible not to speculate here on what could have happened. How would it all have ended if ergot, the most deadly of all the fungi, had not destroyed the Russian cavalry in 1722? Had the Holy Fire not consumed Peter's dream, how might history have been altered? Would it, in 1967, have been New York or Novey Petrograd? Would it have been *da* and *nyet* instead of "yes" and 'no"?

Russia, no matter what its political hue, has never quite given up the vision of Peter Romanov, Czar and Emperor of all the Russias. Six times the Russian armies have attacked Turkey since 1722, and six times they have failed to win the Dardanelles because they never again found the Turks so vulnerable as in the tulip period.

The disaster at Astrakhan was the first clear case of a fungus influencing a military campaign.

Ergotism might have continued to ravage the countries of Europe had not the introduction, in the sixteenth and seventeenth centuries, of a new staple, the potato, supplemented the heavy rye bread of the peasants. Potatoes saved countless thousands of human lives.

Cultivation of the potato spread only slowly through Europe. Botanically it was first cousin, so to speak, of plants with very unsavoury reputations: the deadly belladonna or nightshade, and the erotic henbane, often used by "witches" to induce sexual behaviour in their "clients". But as the European farmers gradually learned to eat the tubers, not the bitter, green berries, the use of rye bread declined. Holy Fire had begun to subside in Germany as farmers learned to clean their rye seed before planting; but as potatoes grew in favour, the incidence and deadliness of ergotism diminished sharply.

In France, however, ergotism continued to break out sporadically even though Dr. Thuillier had proved its cause. In 1777, eight thousand people lost their lives in the Sologne district. In 1816, the peasants of Lorraine and Burgundy were caught up in its flames again.

How did England fare? Because rye has never been a popular grain there, the number of proven cases of ergotism in the medical history of the British Isles can be counted on two hands, except for an outbreak among some central European Jewish immigrants in 1927 who lived on a rye-wheat bread diet for several months. All two hundred of them became ill, but the disease took a mild form.

In 1926–27, when weather conditions were especially favourable, there was an outbreak of ergotism in Russia, with 10,000 cases reported. The last serious outbreak anywhere was, of course, that at Pont-St.-Esprit in August, 1951. But since ergot-resistant rye is unknown, the disease could strike again whenever or wherever man becomes careless.

There is also a happier side to the ergot story. For four hundred years scarcely any other drug has created so much interest. German midwives used it in the 1500's to help women in labour, and it has saved the lives of countless mothers who needed its help. The Germans still call the purple fungus "Mutterkorn" or mother's grain.

For centuries before that, the wise ones, the alchemists, the witches, and even some old grandmothers, had another use for ergot. They knew that the right amount of the purple fungus ground into powder and swallowed would cause a woman to abort. Many a husband through the ages had a barren wife and did not know the reason.

Although the physicians of Europe were well aware of the startling results that sometimes came from the use of ergot as a midwife's aid, they were against its use because of the dangerous side effects that it often caused. Ergot was so poisonous that gangrene or severe convulsions could come from even one overdose. With the development of chemistry applied to physiology at the turn of the century, biochemists turned their attention to ergot. Some of the alkaloids that make up this chemically complex drug were discovered in 1906 and 1918. However, it was not until 1935 when ergonovine, a derivative, was found, that doctors considered it safe for use in controlling undue bleeding during childbirth. In 1943 further technical refinements led to the isolating and transforming of other compounds from the purple fungus. By 1950, twenty chemicals from ergot had been studied, whose use, even in the tiny doses allowed by physicians, could produce startling changes in the human body.

Some of these derivative drugs are valuable in treating high blood pressure. Others help in treating varicose veins. Among the most beneficial are those that help ease an ordinary headache or the severe migraine type.

One of the new ergot alkaloids was discovered and purified in 1938 by Dr. Albert Hofmann in the Sandoz Laboratories in Basel, Switzerland. This new alkaloid, called lysergic acid diethylamide, was set aside for further study and it was not until one day in 1943 that Dr. Hofmann began to put the newly discovered alkaloid through the routine chemical tests. That afternoon, as Dr. Hofmann began his short bicycle ride to his home, his visual perception of the familiar surroundings began to change. Vivid multi-coloured illusions and distortions confused him, and the short ride home seemed to stretch into one of thousands of miles. What terrified Dr. Hofmann most was the feeling that he was floating outside his own body. Gradually, and after a lapse of several hours, his sensory perceptions returned to normal.

The next morning, when Dr. Hofmann went to the laboratory, he was determined to find out what had happened to him. He checked his experiments of the day before and, as he looked at the bottle containing the new ergot compound, he became convinced that somehow he had absorbed some of the new chemical into his body. To test this hypothesis he measured out a tiny dose and swallowed it.

For minutes nothing happened and he began his day's work. Then the wild sensations began to come again. He turned towards the shelf where the bottle containing the strange chemical stood. Before his startled eyes the bottle label bearing the laboratory code name of the new alkaloid shimmered and swelled and seemed to hang in the air, glowing, in the most vivid kaleidoscopic colours. The label filled his whole field of visual perception and the three code letters, LSD, glowed and danced in the centre of his field of vision and beat upon his mind.

His hallucinations grew in intensity, and in his terror he felt he was going insane and would never be able to report his discovery. But next day he was fine again. The new ergot derivative was tested by psychiatrists and workers in mental hospitals. The drug gave them a new insight into the frightening problems that tormented their schizophrenic patients. It was tried as a cure for alcoholism, and people who were distraught were given tiny doses, not much more than one millionth of an ounce. People with behaviour faults, and married couples on the brink of estrangement asked for LSD treatments. They hoped the strange experience would give them the insight necessary to solve their personal or marital problems.

Meanwhile the biochemists found out how to synthesize this new psychedelic drug, and thus its availability increased. The bold and adventurous ones tried LSD in order to experience its bizarre effects. Then the bored and the thoughtless became curious and looked for peddlers of the new drug. For some, the LSD "trips" were good; but others were filled with terror. The teenagers began to experiment with the "acid" and now, for the parents of wayward adolescents, LSD is a more frightening drug than marijuana was a decade ago.

Some authorities say this modern "ergotism" will benefit us; others say that it may prove to be more damaging to mankind than the plagues of Holy Fire that swept through Europe in the Dark Ages.

No doubt many more of the score or so of alkaloids making up ergot will be produced synthetically in the future but, for the present, most of these drugs are obtained from the purple cockspurs of ergoty rye. So many uses for ergot derivatives have been developed that not enough "wild" fungus can be found. Ironically, in parts of Europe where the weather is suitable, where morning fogs are wet and heavy, farmers dust their rye crops with the spores of the fungus to induce a heavy infestation of the purple ergots. These farmers harvest ergot in their rye plots and today make more money from the fungus than from the grain.

2 "Still the Blasting Winds'

WHEAT RUST

Theophrastus of Greece, a pupil and heir of Aristotle, is regarded as the "Father of Botany". In his *Historia Plantarum*, written twenty-two centuries ago, he stated:

"As to diseases of seeds—some are common to all, as rusts. Some are liable to canker and mildew. Generally speaking, cereals are more liable to rust than pulses, and among these barley is more liable to it than wheat. While of barleys, some are more liable than others and most of all, it may be said, the kind called Achillean. Moreover, the position and character of the land make no small difference in this respect; for lands which are exposed to the wind and elevated are not liable to rust, or less so, while those that lie low are more so."

Theophrastus, a meticulous observer, described accurately even the minute features of the plants and diseases he studied. Perhaps he knew then a simple fact few people know even today, that a tiny hole or slit in paper held close to the eye acts as a lens and allows one to observe things at very close range.

Pliny, the first-century Roman naturalist, apparently shared the Roman belief that crop diseases came from the gods or the stars. Whatever the source, however, he noted the Roman wheat was more susceptible than barley to rust. Moreover, he regarded rust as the most destructive of all the cereal diseases.

Greek and Roman philosophers of classical times made a good beginning in man's struggle to learn about plant diseases, but their successors, the Christian scholars of Europe, turned away from natural history and its branches for a thousand years. Until the blinding influences of dogma and scholasticism fell away in the fifteenth century with the rebirth of learning and the invention of printing, men's minds were like dark caves full of fears and frightening noises. Diseases, whether of man, his animals, or his plants, were ascribed to bad luck, evil stars, or vindictive gods. Even as late as 1800 the fungi found on diseased plants were firmly believed to be the dying tissues of the sick plant itself.

Johann Christian Fabricius, a Dane, said in 1774 that these tissues were not the morbid host material at all, but separate plants in their own right. Although some other observers, including the Italian Fontana, agreed with him, many naturalists pooh-poohed that idea. Of course, by this time the fine art of lens-grinding developed by the Dutchman Leeuwenhoek was producing microscopes good enough to enable the eighteenth-century plant doctors to see the tiny single spores of the red rust as well as the double-celled black spores of the dreaded black rust.

As early as 1805, Bénédict Prévost in France and Sir Joseph Banks in England suspected, as did the observant wheat farmers of the times, that red rust and black rust were somehow closely connected. Yet more than half a century elapsed before this suspicion was confirmed by the Tulasne brothers, Louis René, a lawyer turned plant doctor in 1854, and Charles, who left a budding career in human medicine to follow his brother. They proved that indeed red rust and black rust were really two phases of the same disease. Their friend, the German plant pathologist Anton De Bary, who had also deserted medicine for botany in 1865, discovered all but one secret of the life history of rust and its mystifying double life on wheat and the barberry bush. It remained for the Canadian, John Hubert Craigie, in 1927, to clear up the last "dark spot". By finding the plus and minus lesions on the epidermis of the barberry leaves, he made it clear that the barberry plays host to wheat rust while the fungus goes through the sexual stage in which new strains are developed. The subsequent success of the parasite depends upon the virulence of any new strain formed by this sexual union of cells on the barberry leaf.

During the twenty-two hundred years between Theophrastus and Craigie, a multitude of men offered a multitude of ideas—mostly wrong ones—before the main facts of the life history of this most destructive of all plant diseases, rust, were fully understood. However, the plant pathologists found out long before the twentieth century that understanding the life history of a parasitic fungus is not enough. The host plant must be studied in all its phases, too. In parasitism, a form of "togetherness", or symbiosis, there must be a goodly amount of compatibility between the two plants. Otherwise, the parasite cannot live on or in the body of the host or, of course, feed upon its tissues.The plant pathologists had to find methods of upsetting the host-parasite relationship by some means. Chemicals offered seasonal or temporary relief; breeding disease-resistant varieties promised a more permanent solution.

Ancient Greek farmers found the only specific for wheat rust, powdered sulphur. Since the powder had to be spread over the leaves and the stems of each plant, the labour and expense of dusting the multitude of plants to be found in even a small wheat plot made the method impractical. Colloidal sulphur, discovered a few years ago, is more effective than sulphur dust because it contains particles many thousands of times smaller, ensuring more thorough coverage of the leaf surface. Yet even when aeroplanes are employed to spread this better form of the fungicide, the sulphuring method still remains impractical.

About the turn of the century a father and son team, William and Sir Charles Saunders, developed, in a series of crossbreeding experiments, the hard spring wheat called "Marquis". A magnificent milling wheat, it resulted in a bread so soft and so tasty that it has not yet been surpassed. Though the Saunders had not been trying to breed a rust-resistant wheat, the Marquis, ripening ten to fifteen days earlier than the other strains then being cultivated, "hurried" through the summer weather and thus escaped the worst ravages of rust. Moreover, its shorter life-span extended the hard spring wheat growing region farther north into the northwest plains, where it ripened before frost damage. Moreover, the Saunders showed other wheat breeders that two strains of wheat could be crossed to give progeny that combined the good qualities of both the parents and that that progeny, in turn, would "breed true".

Later, William Farrer in Australia and other men working in England, Canada, and the United States succeeded, by crossbreeding and selection of the offspring, in producing not one but several varieties of wheat that were resistant to black-stem rust. But wheat breeders now know that every time a new variety of wheat is developed, the rust fungus, by natural mutations and by millions of matings on the leaves of barberry bushes, is likely to produce new strains to attack the new variety of wheat.

Some 20,000 years ago, the great ice caps that had lain for millennia, heavy and frigid, upon the northern continents of the world, began to draw back. The sun warmed the lands of Europe and Asia that had lain dormant beneath the ice, and the birds and the winds brought the seeds of flowers, trees, and grasses from warmer climates. Slowly, slowly, this land brought forth its abundance. Then men, the wanderers who had retreated far to the south, came back; they tasted the earth's abundance, and found it good.

No tangible proof of ancient man's struggle to repossess these lands remains now, except for a bone here and there, some middens, a few ruins buried in the shifting sands, the great tombs of kings, and hazy remnants of myths and legends.

A century and more ago the palaeontologists, and the archaeologists, began their patient searching and digging. First, they studied the rocks and the tombs, and then the cities. Later, realizing that cities are but end products of man's civilization, they began to dig deeper and search farther away from the plains and up into the hills for earlier signs of man's story. They were looking for traces of the men of the land, the farming men of ancient times who lived on the land long before the first towns and cities. Agriculture is the ground work of all social order, and obviously, no city can exist without food. It is true that many modern cities get their food from far off, for our means of transportation now are wonderfully swift and efficient. But thousands of years ago, farmers scratched their land, tended their crops, and herded their domesticated animals nearby, from the hills, across the plain, right up to the walls of the cities themselves.

It has been known for a long time that one of the earliest centres of civilization lay in southwestern Asia. There, ten thousand years ago, a potentially rich land known as the Fertile Crescent lay cradled in a great range of hills that ran in a wide arc for about 1,500 miles from southern Palestine, north through Lebanon and Syria, across the south of Turkey, and down through northern Iraq into Iran to the Persian Gulf. For centuries the Fertile Crescent lay untouched, nurtured by the rains, between two great rivers. Man hunted there for ages and then, pushing farther north into the hills, he found a veritable treasure of wild sheep, goats, cattle, and wild plants.

Some ancient man noticed a peculiar heavy-headed grass. He munched at the doughy kernels of those first cereals and liked them.

Even today wild wheat and barley can be found in those mountain valleys 2,000 to 3,000 feet above the arid plains that lie to the south. The climate then provided generous winter and spring rainfall, and there were innumerable pleasant little valleys where the soil lay deep and rich. These mountain men, the first farmers, were quick in intelligence and industry, and there is ample proof now that 7,500 years ago the first plots of cultivated wheat were harvested all the way from Natuf in Palestine, Amouq in Syria, Jarmo in Iraq, to Tepe Sarab in Iran. The easily domesticated animals, the wild asses, the oxen, gave man more power to work his bigger grain fields. And so the great agricultural revolution began.

The cereal grains are the precious metals of man's food supply, and of these grains, wheat is the gold. Wheat is easily grown, and its kernels are concentrated packages of the richest food, full of carbohydrates, fats, proteins, vitamins, and minerals. Wheat can be stored for years with little loss in food value. It can be transported easily because it is relatively dry and light. Above all, wheat and the foods made from it are very digestible and pleasant to the taste. Long ago man ground it between crude milling stones into flour and baked it into bread.

Little wonder then that the cultivation of wheat has spread so widely from the Palestinian and Syrian hills. Today the farmers throughout the world harvest ten thousand million bushels of its golden kernels annually.

The story of wheat culture would seem to be a simple one of planting, weeding, harvesting, and eating. It was easy enough for intelligent and industrious farmers to prepare the soil, to sow, and to harvest. But there were difficulties, too; floods and hail and drought and locusts and plant diseases drowned, beat down, nibbled, and blasted the wheat. Floods tend to be localized, hail runs in strips through the fields, and insect damage tends to affect only a limited area. But what of drought and disease? To grow his wheat man moved to the valleys or plains whereever rainfall seemed likeliest. But disease struck everywhere, most severely when the crops were most luxuriant, and of all the diseases of wheat, rust was by far the worst. Even now, in spite of all the great forces of science, the rust fungus still is the greatest blaster and ravager of grain crops.

Wheat, then, originated in the hills of Asia Minor, and evidence points to the same region as the place of origin of the barberry, meadow rue, and some other plants that served as the alternate hosts of the many rusts. Here, in Asia Minor the fungus had learned to skip back and forth from the one plant to the other. The cerealists believe that, millions of years ago in the hills of the Fertile Crescent, the fungus developed its curious life history. The wild wheats and barleys, along with other grasses and cereals, must have been badly infested with rusts. Ages later, when man planted his wheat there, he watched his crops sicken from the red scourge, never once suspecting that the inoculum for the disease came from the little bush with its bright red, sweet-and-sour berries that grew so prettily near his fields.

The wheat plant alone can be seriously plagued by three related rusts. Stem rust, the most serious, is caused by a fungus with the mouth-filling scientific name of *Puccinia graminis tritici*, so named by C. H. Persoon, to honour his biology professor, Puccini, who taught in an Italian university about 150 years ago. The specific name *graminis* comes from the Latin word for grass and *tritici* from the word for "thresh by rubbing". Closely related fungi cause leaf rust and stripe rust.

These three rusts may have attacked the ancient farmer's wheat crop simultaneously because the weather conditions that favour any one of these favour all three. The germination of their one-celled spores, carried to the wheat plant by the winds, is aided by warm rains, fogs, and heavy dews.

The colours of the summer spores, the urediospores, all lie in the red-yellow end of the spectrum. Those of stem rust are a dull orange-red, a colour closest to the rust of iron from which the disease is named. The urediospores of leaf rust are a brighter orange, and those of stripe rust are tinged with yellow. Of course, one cannot see a single spore with the naked eye, let alone tell its colour. Even when viewed at a magnification of 500X the spores look like tiny oval beads. However, when thousands of spores erupt through the epidermis of the wheat leaf, they form a coloured pustule that can be seen without a microscope.

Wheat can be attacked by these rusts at any period in its growing cycle once its tissues are green and active. The earlier the infection, the more serious are the results. However, when the weather is cool and dry, few rust spores germinate, and under such conditions damage to the plant is slight.

The most common alternate host for stem rust is the barberry bush. Leaf rust has at least two alternate hosts, a little bush called the basilisk plant, and a perennial evergreen shrub, the meadow rue. The infection of wheat can be caused by either the red spores from other wheat plants and related grasses or from the "honey" spores, which are the aeciospores, from the alternate hosts.

When either of these spores settle down on the wheat leaf, it germinates by sending out delicate germ tubes. In their growth, these germ tubes squirm outwards seeking blindly for the tiny mouthlike openings (the stomata) on the leaf epidermis of the wheat. Since both surfaces of the wheat leaf have thousands upon thousands of stomata, it is not difficult for the germ tube to find in its blind probings an opening that leads to the food treasures of the leaf. When the rust germ tube reaches down to one of the leaf cells it grows a special thumblike projection which it uses just as Little Jack Horner used his thumb. These little projections (haustoria) push into cell after cell as the fungus thread grows and branches through the interior of the leaf at a tremendous rate. Thousands of cells are punctured and drained of their soluble foods.

In a week the fungus threads that form the body, or mycelium, of the fungus, tap enough food-producing cells in the wheat leaf to begin to form spore-producing structures. The structures, pushing outwards on the epidermis of the leaf, create enough pressure to rupture it. The mass of spore-producing structures that contain thousands of powdery reddish-orange spores form the characteristic rust pustule on the wheat leaf. Each pustule produces 2,000 or more spores per day for two or three weeks. These red spores, each capable of starting a new rust colony on any wheat leaf to which it adheres, in turn are spirited away on wind currents.

The chain reaction thus started will continue as long as the weather is favourable for the rust spores to germinate. The result is a most phenomenal saturation of the earth's atmosphere, so that every cubic foot of air contains dozens of these spores. During exceptionally favourable conditions, more rust spores are produced in the world than there are blades of grass or grains of sand on all the world's beaches or stars in all the galaxies of the universe. In some of the bad rust years in Eastern Europe the dews were yellow with spores, and the fogs and rains were as red as blood. Small wonder, then, that each wheat plant is soon spotted with a pox of hundreds of rust pustules, that the fungus mycelium within weakens its tissues until the wheat kernels, when they finally ripen, emerge withered and shrunken.

These three rusts, when they infect the wheat plant, do not, like heavy-handed ruffians, tear and consume the body of their unfortunate host; but rather, like light-fingered pickpockets, they drain the host tissue of its vital supply of foods. And because they do not kill the host plant they are successful parasites.

As the wheat plant approaches maturity, its life processes slow down. To this subtle change in the host plant, the rust parasite readjusts, forming large double-celled spores, called teliospores, that have thickened walls. These black teliospores lie dormant in the fields on the stubble and harvest debris through winter storms and intense cold. In the early spring each black spore germinates into a stubby clublike structure, a basidium, and each club grows four little spores, basidiospores, that loosen and blow away on the spring winds.

If these little spores fall on the young spring leaves of a barberry bush, as in the case of stem rust, or on the leaves of the basilisk or meadow rue, as in the case of leaf rust, they germinate. Stripe rust goes through the same cycle, but as yet no alternate host has been discovered.

On the alternate host, the rust fungus goes through its sexual stage, producing small receptacles on the upper surface of the leaf where mating occurs between the various strains of rust produced there. At that time large pustules burst through the leaf's under epidermis. The aeciospores formed in these pustules are light enough to be blown dozens of miles on the fresh spring winds to infect the young wheat plants.

Here, then, on the barberry, the basilisk, or the meadow rue, the rust fungus, by blind chance and by its myriad matings, challenges man's skill and intelligence. The matings of races or strains produces new variations with enough differences in their hereditary make-up to form new races of rusts capable of infecting the many varieties of wheat that man has painstakingly developed by selection and breeding in the last half century. Almost every new variety of rust-resistant wheat developed artificially by the wheat breeders has, after a few years of cropping, been successfully parasitized by some new and virulent race of the rust fungus.

Who will win this vital struggle for one of the world's greatest foods?

The prize is a rich one.

If all the little plots and fields of wheat were put together they would form one great field a thousand miles square. A great field, indeed! In fact, such a field would be about four times as large as the state of Texas. The harvest would form a pile of golden wheat as huge as Mt. Vesuvius. However, if the weather is "right", the rusts flourish, and in a bad year the fungus would devour a quarter, a third, or even one-half of the world's annual wheat crop.

Such recurrent losses of food have had a great influence on man and his civilizations. To assess some effects of the ravages of the cereal rusts we must look back to ancient times.

Our first knowledge of famine that can be attributed to rust is in the Old Testament. Some 1,800 years before Christ, there lived in the green hills of Palestine a man named Jacob. He and his sons and their families and their servants and their neighbours were wealthy in land, crops, and domesticated animals. And Jacob had a favourite son, a boy who was a dreamer, not interested in either grain or crops. His brothers were angered by the boy's dreams, dreams that seemed to demean them in their father's eyes. So the brothers plotted against Joseph and, when an opportunity came, they sold the boy as a slave to a passing trader who was going south to Egypt. The brothers took Joseph's cloak, dipped it in goat's blood, and took it to their father. Jacob mourned a long time for Joseph, believing he was dead.

When the caravan reached Egypt, Joseph was sold again to a captain of Pharaoh's guard. Joseph prospered in Egypt, for he was exceedingly clever and faithful, and the captain made him overseer of his estate. But because he scorned the charms of the captain's wife she turned against Joseph accusing him of adultery, the very act he would not commit. In those times adultery was a heinous crime and Joseph was imprisoned.

As chance would have it, two of Joseph's cellmates were servants of Pharaoh himself. And when they dreamed, Joseph interpreted their dreams. He said that one would be released and come into favour again with Pharaoh, but the other would be hanged. And it was so.

Two years passed—and Joseph was still confined in an Egyptian dungeon.

And then Pharaoh had a dream.

> And, behold, he stood by the river.
> And, behold, there came up out of the river
> seven well favoured kine and fatfleshed;
> and they fed in a meadow.

And, behold, seven other kine
came up after them out of the river,
ill favoured and leanfleshed;
and stood by the *other* kine
upon the brink of the river.

And the ill favoured and leanfleshed kine
did eat up
the seven well favoured and fat kine.

Then Pharaoh awoke but could make nothing of the dream. Presently he slept again and dreamed again.

and, behold, seven ears of (grain)
came up upon one stalk,
rank and good.

And, behold, seven thin ears
blasted[*] with the east wind
sprung up after them.

And the seven thin ears devoured
the seven rank and full ears.[†]

Pharaoh could not understand his visions and called all the wise men of Egypt to him. Even they could not interpret his dreams. Then Pharaoh's servant heard of this and, remembering the young Hebrew prophet in the prison, told Pharaoh of him and his strange power. Pharaoh summoned Joseph to him and Joseph interpreted his dreams.

The two dreams were one and the same, he said. The seven good ears of grain in the dream meant seven good years when the crops of Egypt would be plentiful, and the seven ears blasted by the east wind would be seven years of famine when the crops of Egypt would fail. Pharaoh was much impressed with the young man's wisdom and made him ruler over all the land of Egypt.

During seven good years, Joseph stored all the surplus grain in the granaries which he had built in Egypt. Then came the seven years of crop failure, when the east wind blasted the grain.

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[*] The Hebrew word "yeraqon", which means yellowing, was translated in the King James Version of the bible as "blasting" or "mildew". The German translators did better when they rendered "yeraqon" as "rust", since the mildew fungus is white, whereas the rusts range from yellow through orange to red.

Rusting is mentioned in the Bible in (1 Kings 8:37; 2 Chronicles 6:28; Amos 4:9 and Haggai 2:17.)

[†] Genesis 41:1-7.

To determine what kind of an east wind, we must consider the climate of the Near East at the time.

Many climatologists believe that 4,000 years ago the long-term average of the mean annual temperatures was several degrees lower than that which prevails now. Perhaps that was because of the fingers of the glaciers that still lingered in the high mountains of Asia Minor. Certainly all those lands were much more heavily forested then, and where there is a large forest covering a region there is more residual moisture and a cooler climate.

Even now the great cyclonic storms sweep eastward over the Mediterranean and bring moisture to the Israeli coast in the winter and early spring months. We know that rain comes with these cyclonic storms on the forward side of the area of low-air pressure. The winds of these great storms circulate in a counter-clockwise direction. Therefore, for a day or so before the low-pressure area with its vanguard of heavy rain clouds sweeps over the coast, the prevailing winds are from the east and the southeast.

There we have it. The east wind is the harbinger of rain. Thus we can conclude that Pharaoh's east wind presaged moisture and plenty of it. So the east wind was a wet wind and not a dry, drought-creating wind.

There is no mention in the Bible of the crops having been flooded out. How, then, could a wet wind cause famine? By bringing wheat rust, of course. All that the rust would need was rain and mists and more rain and heavy dews. The barberry bushes, the other hosts, and the wild wheat that were abundant in the Syrian hills nurtured the rusts. The shifting winds of the great cyclonic storms would spread billions of the red spores. With the wheat crops blasted by rust, famine lay heavy on the lands of the Levant coast.

Jacob, hearing of the great stores in Egypt, sent his sons to buy food there. They did not recognize their brother Joseph, and for two years Joseph commanded that their sacks be filled with grain before he told them who he was. Because he was ruler he had the power to send for his father and all his brothers and their manservants and their maidservants to come to the land of plenty. And so the Israelites entered Egypt.

They were given the land of Goshen to live in. Biblical scholars are not sure just where Goshen was in ancient Egypt, but it probably lay in the high country to the east and south of Cairo because it was free of the plagues that came to Egypt later in Moses' time.

The children of Israel lived in Egypt for four centuries. At first they were free men and were respected for their wisdom and industry, but towards the end of their sojourn in the land of the Pharaohs they lived in grievous slavery, and every man's hand was against them.

Then came Moses who led the Israelites out of bondage across the Red Sea into the desert. Here they wandered as nomads in poverty and hardship by the design of Moses the wise. He knew that the land to which he planned to lead them was already settled by a tough and wily people, the Canaanites. The children of Israel would have to win their promised land by force of arms. But the poor souls he led from Egypt had had their spirits broken by the whips of their masters. He waited forty years for the generation that had been enslaved to die and for their offspring, the young men, to be toughened and tempered by desert hardship and hunger into a veritable steel blade of fighting men. Then he brought them to the banks of the river Jordan.

How different would the history of the Hebrews have been had they not been forced by the red scourge of rust to emigrate to Egypt? No man can say. But this we do know, that except for the culture of the Greeks and Romans, the Hebrew culture has had the greatest influence in the shaping of our modern Western civilization.

Would these simple farming people have made any mark at all on the social order of the world had they not suffered the famine, the bondage, and the Exodus?

Would there ever have been a Moses?

And what of the Ten Commandments?

Once again we are forced to realize that the impact of a single plant disease can reverberate through the centuries from ancient times to the present.

Little is now known of the wheat culture of the ancient world during the eight centuries after the Exodus. It was not until 500 B.C. that the Greeks began to write of this new grain. How the ancient Greeks learned of the "king of the grains" will forever remain a mystery. It is unlikely that their ancestors, the wild, nomadic tribes that pushed down from north of the Danube centuries before brought the grain with them, for wheat did not have its origin in the forest lands of northern Europe. The Greeks had been growing spelt, a relative of wheat, for centuries; but shortly before the Persian Wars the Greek traders brought wheat to their homeland.

Because of the nature of their country, with its rough coastline and many safe harbours, the energetic Greeks had taken a great interest in the sea. The many islands of the Aegean served as stepping stones to the east and south, so that as early as the thirteenth century B.C. the eastern Mediterranean had become a great broad highway for the Greek galleys. They sailed to the western edge of Asia Minor, to the Levant coast, and even to Egypt.

From one of these places an amphora full of wheat came into the hands of Greek traders who recognized the value of this grain, if kept dry, as an imperishable article of provision on their long voyages. They saved seed for the homeland farmers, and soon green plots of wheat patched the valleys of Greece.

But the gifts of the gods do not come unmixed. When this wonderful grain grew wild on the high plains and fertile parklands of western Asia, the distance between the scattered plants helped to protect them from their fungus parasites. But when the Greek farmers began to plant wheat, the warm wet spring weather of the Mediterranean coastlands made it easy for wheat's ancient enemy, the rust, to develop its red spores and spread rapidly among the crowded plants. Thus history records that rust was destructive to the wheat crops of Greece centuries before the Christian era. Even Aristotle wrote of rust, noting that its severity fluctuated from year to year, and reporting that the farmers of his day (about 350 B.C.) thought it came from warmth and moisture.

Theophrastus, Aristotle's student, wrote that periods of warm sunshine following the heavy dews of the Greek spring seemed to bring rust to the wheat crops growing in sheltered valleys.

Although the philosophers understood the weather conditions that promoted the rust attacks on the wheat, they could not tell the simple farmers how to combat the disease. The peasants turned to the gods. Strabo, writing about the time of Christ's birth, tells of the Greek farmers still praying to Apollo, the sun god, for relief from the rusting of their wheat.

Farther to the west in the balmy Mediterranean climate, the Roman farmers also were ignorant of the remedy for this terrible sickness that laid waste their crops and withered the wheat kernels. When rust made the grain useless as food or seed for the next year's planting, they went to their priests for help. The priests knew that Jove, Mars, Ceres, and the other gods were already burdened to the limit with man's affairs. So in 700 B.C. they found one more god, Robigus, the god of rust.

The great procession streamed out through the gateway in the massive wall of Rome, the City of the Seven Hills. Flickering torches held aloft by priests tinged the white robes with orange and yellow and deepened the ruddy faces of the farmers who were following them. At the end of the procession came hundreds of devout and hungry pagans of the city, awed by the solemn chanting of the priests of Robigus.

There was little food in the city that third week of April, 121 B.C. The year before the crops had failed, blasted by rust. The grain ships from Egypt and the African coast had docked half empty, and the hungry Roman mobs clamoured for bread. Gaius, the last of the Gracchi brothers, had argued against the hoarding of grain and the high prices the magistrates were charging. But while the great men of the land had debated, the people had turned in desperation to their rust god. If Robigus would heed their prayers this holy night, all might still be well.

As the procession turned from the stone-paved way into the sacred ilex grove, the chanting stopped. There was the white altar, brightened by the flames from hundreds of torches. The head priest of Robigus stood on the high dais, his arms outstretched, his face upturned to the black sky. The worshippers took their places in silence. Two priests mounted the stairway to the altar as their brothers raised their voices in a solemn chant to their god. One of the two carried in his arms the animal for sacrifice, a red dog, cringing and whimpering in its terror. The other bore the sacrificial knife.

With the flash of the knife the chanting stopped. No sound broke the silence but the gentle soughing of the soft spring breeze through the ilex grove. Suddenly, the high priest began the opening prayer.

> Stern Robigus spare the herbage of the cereals,
> Withhold thy roughening hand
> We pray you leave the sown crops to grow
> Let them be nourished by the stars of a favourable heaven
> May their heavy heads on the high ground
> Billow under the summer's breeze
> Like running seas.

Spare our crops, O Robigus.
Is it not enough that thou couldst harm them?
Accept, O mighty god, our sacrifice.
Take it, O Robigus, and not our wheat!
Drink the red wine O god!
As we stand humble before thee.

The high priest paused as the contents of a golden vase spilled upon the bloody altar. The red wine blended with the red dog's gore, and a great chant rose from the choir of priests.

The high priest's prayer continued:

Spare us from the baleful glare of Sirius the dog star.
Still the blasting winds from the eastern sky,
Grant us our crops, the labours of our hands,
And we, in holy gratitude
Will honour thee forever more.

Then came the ritual of the burning straws. More chants, more prayers, until Sirius, that ominous star, dipped slowly to the west and sank past the sacred trees.

Then, and then only, did the ceremonies end and the reverent marchers, their minds content, retrace their way along the flagstoned road towards the sleeping city.

Everything had been done by the priests in the right way and at the right time to propitiate Robigus, their rust god. Now it remained only for the farmer by his own prayers in his own fields to ward off any lingering anger of that great rust god. Some of the simple Roman farmers planted laurel branches among their wheat, for they believed that if Robigus had not been calmed and placated by their prayers, the rust would collect on the laurel and not on their crops.

Other Roman wheat farmers, however, heeded the advice of Cato, the ancient Roman writer: wheat should not be planted in land where there is fog and mist. This admonition of Cato's may have been difficult to follow because the weather conditions in the Mediterranean region had begun to change.

Historical writings and the study of the growth rings of the great old trees from the Mediterranean area, along both the European and the African shores, show that the climate in the first three centuries after

Christ's birth was unusually wet. Rust flourishes in wet weather, so the crops of the widespread Roman Empire must have been ravaged many times by this disease. When crops failed, there was hunger. Where there is famine, the people fall easy prey to their own devastating diseases. Typhus, plague, and other decimating scourges of mankind helped to destroy Roman civilization. Weakened from within by the destruction of their food supplies and the resulting human diseases, and beset from without by the barbarian hordes, the Roman Empire suffered a steady deterioration in stamina and zeal until the whole structure of the state collapsed.

For centuries after the disintegration of the Roman Empire the peasants of France, England, and Germany planted their wheat seed in the mellow loams of Western Europe. This treasured grain that the Romans had brought north flourished, protected by the high mountains of Central Europe, the Alps, and the peaks of Bavaria that blocked the east winds from Asia Minor. The dread stem rust was virtually unknown to these farmers of Western Europe.

But a great stirring of another sort had come far to the east in the arid sands of Arabia. A prophet had arisen, and the Arab tribesmen had caught the grandeur of his visions. "Spread the faith of Islam," Muhammad thundered to the Arabs. "Spread the faith by sword among the unbelievers! Spread the faith of Allah in the four directions." And the Saracens, warriors of Islam, galloped to the east, to the north, to the south, and westward all along the northern coast of Africa to the gates of Hercules. Their converts, the Moors, crossed the narrow strait into Spain and conquered that country. They ravaged all southern France as far north as the river Loire, where Charles Martel, the Hammer of the Franks, defeated them and pounded them back across the Pyrenees.

Later, the Crusaders, in attempts to win the Holy City from the infidels, renewed the struggle and continued hostilities for two and a half centuries.

Who won? Neither Christian nor Muslim. When both sides became exhausted, the fighting subsided. Gifts were exchanged, and the Christian and Muslim worlds settled into peaceful coexistence.

The Christian warriors learned of many new and wondrous things. They saw the rich lands and the voluptuous style of living of the East.

Some of them learned mathematics and medicine from the Arabian scholars. The returning hero knights brought their ladies rich silks, fabulous jewels, and many other lovely gifts. But in a material way the Christians lost more than they had gained.

One Saracen invader, lonesome for his own country, brought with him a lovely little bush. He planted it somewhere in Sicily to remind him of the hills of Syria. Its beautiful green foliage and its bright red berries eased his homesickness in that strange land.

The birds liked these berries, and the seeds were carried far and wide. The peasants, too, found the pretty bushes "good" because the golden wood, when boiled, yielded a potion they came to prize for various ills. And the berries made the tastiest of jams and jellies. Neighbour gave cuttings to neighbour, and the barberry flourished and spread up through France to Denmark and beyond. But with the barberry came its deadly fungus parasite, the black stem rust of wheat. No one seemed to notice the little dark yellow scabs upon the leaves of the bush—or if they did notice they saw that the bush was little harmed by the spots. But they did see that a strange sickness had come upon their fields. Myriads of red spots erupted on the lush, green leaves of their wheat. Their crops sickened and rusted. Hunger came to Western Europe.

We know now that successful wheat farming is impossible when wild barberries grow near the fields. In the 1920's some trained agriculturists in the Mississippi valley, finding a circular area ten miles across where the farmers' wheat was virtually destroyed by rust, searched until they found a single barberry bush at the centre of the devastation. That one bush, in a single year, had caused nearly $150,000 damage to the wheat crops of the surrounding countryside.

Cause and effect is the great watchword of science now. In the Middle Ages, however, the peasants whose very hedgerows were solid barberry only shook their troubled heads and suffered their disappointments and their hunger. A hundred spurious reasons for the rusting of their crops flooded their minds. It was the will of God, said the devout. The land has run down, said others. Some fiend, some evil spirit, perhaps Flibbertigibbet himself has ruined our wheat with the black rust, still others claimed. No one guessed the right answer for hundreds of years.

Then some observant farmer near Rouen, France, saw that wherever there was a rusted wheat field there were barberry bushes nearby. He told his neighbours. They looked and saw. They clamoured for the government at Versailles to do something. The legislators not only sent scientists, but many came themselves. What they saw convinced them that rust and the barberry were connected. They went back to Paris and passed a law in 1660 to tear up and destroy the barberries. Millions of bushes were uprooted. The first barberry eradication law in the world came into effect, and it seemed to help.

Slowly the idea spread until Germany, Denmark, Austria, and Russia took action against the bushes that harboured the sexual stages of wheat's greatest destroyer, the stem rust. But the bushes are hardy and tenacious, and some still lurk in the moors and woods of Europe to present rust with an opportunity to develop new and more virulent races of the fungus.

What of the New World?

The Spaniards from Europe brought wheat. Three seeds of it came to Mexico in 1528 in a rice shipment. The English brought wheat with them to the new settlements along the Atlantic Coast. They brought the common barberry too. That, and two species of barberry native to North America, served the rust fungus as alternate hosts in North America. In 1726 the first barberry eradication law was enacted in Connecticut, and Massachusetts passed a similar law in 1755, and the fight against the barberry has gone on ever since, without success. Despite several programmes of eradication, the barberry seems indestructible, and man must try to solve the rust problem by other means.

Chemicals?

Dusting the sick wheat with powdered sulphur is still the best fungicidal treatment that man has discovered. There have been newer chemicals put on the market and used, but the sad truth is that no fungicide against the rust is practical because, at the very least, three applications must be applied annually. The cost is simply too great for profitable wheat growing.

About the turn of the twentieth century, wheats from Russia and other European countries were planted in the United States. Of these, a durum wheat from Italy and an emmer wheat from Russia were found to be rust resistant. This was a hopeful discovery.

It was about this time that the Saunders were successful in producing Marquis. Unfortunately, this new wheat was not resistant to rust, and the bad rust year of 1916 doomed Marquis as a reliable variety. However, plant breeders were able to cross Marquis and Kota (a resistant

Russian wheat) to produce the first artificially rust-resistant wheat. It was called Ceres. Meanwhile, the black stem rust fungus had developed its race 56,* and in 1935 the millions of fields of Ceres wheat were severely damaged.

Thatcher, another wheat with Marquis parentage produced by American wheat breeders, became the most important wheat on the Great Plains of North America. Unfortunately, Thatcher was not resistant to leaf rust and had to be discarded as a profitable variety. New rust-resistant varieties replaced Thatcher, but the fungus again produced a new race, called 15B by the plant pathologists. This strain of black stem rust, first observed in Iowa in 1939, had become very troublesome by 1950, In 1953, race 15B devastated the spring wheat crops of North America with losses of up to 75 per cent in durum wheats and 35 per cent of the bread wheats. Once again new rust-resistant wheats had to be bred and selected. Almost certainly geneticists and agronomists will have to continue to develop new strains of wheat to keep one step ahead of the wheat-rust fungus. So far, no other means of control has been successful.

Nowadays, even with modern technical aids and statistics, estimates of crop losses are approximations; but the estimates from 1700 to 1900 were often merely guesses.

Only the very bad rust years seem to have been mentioned at all. The recorders of agricultural developments seem to have derived their information from limited personal observations and word of mouth reports by farmers, travellers, and the like. From what they wrote, it is therefore often impossible to tell whether crop losses resulted from a specific disease or from other causes. It seems, however, that almost every year from the 1700's to the 1930's saw the rusts reduce the yield of wheat, damaging its quality for bread making and its viability for the next year's seed.

Tull says that England, in 1725, suffered "a rust year the like of which man has never seen". The Boers in South Africa suffered severe losses in 1708–10 and in 1727. Italy incurred losses from rust in 1766 and Sweden in 1794. English wheat crops were rusted in 1804, during the 1820's, and again in 1881–82. India suffered from the red scourge in 1827 and 1839. In 1916 rust struck the Canadian and United States plains, and in 1927 the Canadian prairies suffered serious losses. Russia lost about one-fifth of the Siberian wheat crop to rust in 1932. In 1938 the loss from leaf rust in the United States ran to 100,000,000 bushels, and strain 15B of the black stem rust cost Canada and the United States, in 1953–54, about 200,000,000 bushels of golden wheat.

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* The different varieties or strains of rust that develop on the wild barberries are designated by number—thus "race 56" is the fifty-sixth wild variety of black stem rust that came to the attention of the cereal plant pathologists.

Taken altogether the cereal rusts are estimated to cause an annual loss of $500,000,000 per year. This amount of grain, if it could be saved, would help keep the two thousand million hungry people of the world from having to subsist on a starvation diet.

The annual world production of wheat is greater than either rice or corn and thus it is the most important food crop. Each year more than 250 million tons of this grain are harvested. Any disease that threatens the wheat crop threatens mankind.

3 The Insidious Black Harvest

THE GRAIN SMUTS

The word in Norwegian is "smuss" and in Danish, "smuds". The Germans call it "schmutz" and the English word is "smut".

This word, however you spell it, comes from the old Gothic tongue, parent to all the Teutonic languages. In all of them, the literal meaning is dirt or excrement and in the figurative sense, at least in our language, filthy or obscene. By connotation smut suggests corruption or evil. It is not strange that when the English became more discerning towards plant diseases they gave up the old generalized names of "blight" and "mildew" and called the dirtiest and most insidious agricultural plague of them all—"smut".

No direct reference to smut of cereals has been found in the writings of the ancient scholars. The Greeks and Romans had no specific name for the disease. The biblical writers lumped all grain sicknesses together and called them "blasting" or "mildew". Pliny wrote of the "corruption" of wheat, but we can only guess at his exact meaning. In more recent times Bacon wrote that "Mildew falleth upon corn and smutteth it", but at best the quotation demonstrates the interchangeability then of the words "mildew" and "smut".

It took a farmer to pinpoint smut as a definite plant disease. The first direct reference to this disease was made by Jethro Tull, the English agriculturist who also invented the first seed drill, an implement which, if dragged or pushed across the field, made little furrows into which the seed was mechanically dropped and covered with soil. Tull studied every aspect of wheat farming from sowing to harvesting, and with simple clarity reported about 1700 that "Smuttiness is when the grains of wheat, instead of flour, are full of a black stinking powder".

In 1755, Monsieur Mathieu Tillet, Keeper of the Mint at Troyes, while poking about the wheat fields of France, saw that there were really two kinds of smut. One he called *la carie.* At first glance the infected wheat plants seemed healthy enough; closer inspection showed their heads to be filled not with sound grain but with brownish balls full of a black, foul-smelling powder. This is the disease the English call "bunt" or "stinking smut".

The second disease left the wheat plant apparently whole and sturdy, but when the time for harvesting came, the head had no grain at all. In fact, nothing was left of the head—no grain, no chaff, nothing—except the central rachis or spike, which was covered with a loose, black powder that blew away on the autumn winds. This disease "loose smut" to the English, Tillet called *le charbon.*

M. Tillet found time for many interests besides the King's coinage. He had a bit of land, but his farming was only a hobby. Much of his spare time was spent in studying farmers' problems, not the least of which were the smuts he had been observing. Little wonder, then, that when the Academy of Arts and Sciences at Bordeaux announced in 1750 that a prize would be given for the best investigation into the smutting of wheat, M. Tillet entered the contest with characteristic zeal. He wandered about the wheat fields of central France observing the sick crops and listening to everybody. More importantly, he used his little piece of ground to test a number of theories then held regarding the cause of smut. Was it sunstroke? Or soggy ground? Could it be the insects that flitted and crawled around the heads of the grain? Perhaps the smut was caused by the type of manure used, or by the treatment or lack of treatment of the seed. Could it in some mysterious way be bound up with the phases of the moon? After much thinking Tillet formed a hypothesis, rolled up his sleeves, and began his famous set of experiments with 120 little plots of grain.

The next year he repeated his experiments with similar results. Smutted wheat sprang from seed that had been dirtied with the black dust from the smut balls of the preceding year. The type of manure used did not matter. The time of seeding made no significant difference. The weather had no appreciable effect. There was no doubt in Tillet's mind: the disease was seed borne, and the infection was caused by the black smut dust.

The judges in Bordeaux read Tillet's magnificent report with astonishment. Not only had M. Tillet proved that when a farmer planted his wheat he planted the covered smut inoculum along with the seed, but in the same series of experiments he had found a remedy.

He had tried washing the seed grain—some in water, some in the urine of cattle, and some in lye solutions. Some he soaked in lime and salt. None of these seed treatments eliminated smut entirely, but each helped to suppress it. Most important of all, the steeping of the seed grain showed the way for other workers who followed.

Monsieur Mathieu Tillet was awarded the prize.

In a way Tillet had verified his hypothesis concerning the cause of bunt, or covered smut, on very flimsy evidence indeed. Although he peered through his microscope at the black dust from the broken bunt ball, the crude instrument did not allow the specimen to be seen clearly. Was the black dust from the bunt ball just the corrupted matter of the diseased grain? Or was it a mass of the "seed" of the fungus, the fungus spores? Tillet could not tell. Another half century passed before M. Prévost of Paris, with a better microscope and a lucky thought, made the next discovery. He placed some of the black dust in water and examined it daily under his microscope. First day—nothing. Second day—still nothing. But on the third day Prévost saw little stubby sprouts growing from the particles. They were germinating spores of a fungus after all.

Prévost watched these sprouting spores hourly. At the end of each sprout a starlike growth appeared that became a microscopic, colourless, onion-shaped plant. With sudden insight Prévost understood how the bunt organism could infect the wheat. These bunt spores clung to the grain when it was sown and germinated in the damp soil along with the wheat. Somehow the sprouting spores pushed their bodies—perhaps the sharply pointed ends—into the tender tissues of the germinating wheat plant. Prévost saw that once having gained entry, the fungus pushed upwards in the young stems to the very apex, the head where the blossoms formed, and the kernels began to develop. Here was where the corrupting force of the fungus destroyed the grain.

Rich in proteins, fats, and starches, the young developing seed was a fine and safe place for the hyphae, the threads that make up the mycelium or body of the bunt fungus, to fruit. Inside the protecting seed coat, the smut fungus looted the food-rich cells of the wheat kernel. By the time the healthy wheat seeds in the field ripened, the corruption of the infected kernels was complete. Every bunt ball contained at least a million smut spores, and when harvesting operations ruptured these balls, the spores were disseminated high into the air. They lodged on the surface of whatever healthy wheat kernels there were in the harvest, or they fell from the air into the soil as veritable showers of spores.

Prévost never saw the fungus threads (hyphae) in the stem or leaf tissues of the wheat, but he did observe the developing spores in the bunt balls and, almost by accident, he found a better preventive for wheat smut than Tillet had found.

One day he saw through his microscope that the bunt spores were not germinating as readily as they had before. They grew for a few hours and then shrivelled and died. Prévost remembered that he had distilled the water. He repeated the experiment with well water; the spores grew. He tried the distilled water again, and the germinating spores of the smut died quickly. When he ran it through the still, was he taking out of the well water something essential to the growth of smut? If only the germination of the spores in the soil could be prevented, the wheat could be saved. But a farmer could not distill the soil water, nor the rain.

Prévost might well have abandoned his efforts at this point but for a wheat-growing friend's chance remark. In conversation, the farmer stated, almost boasted, that on his farm there was no bunt and had not been for years. Prévost began to question his friend closely. Did he treat the wheat seed? Yes, but so did his neighbours, yet they often had smut in their fields. Did he use lime? Yes, but so did the neighbours. Did he steep the seed? Yes, but the other farmers did likewise. Then, almost as an afterthought, came the revelation: "My neighbours steep their seed grain in wooden vats but I use a huge cauldron of copper!"

Prévost's gaze left his friend's face and darted towards the still in which he distilled the water—the water in which the bunt spores would not sprout. It, too, was made of copper!

Prévost could scarcely wait until his friend departed to begin a new series of experiments. In a week he was sure. The slightest trace of copper prevented development of the germinating bunt spores.

In 1807 Prévost suggested that copper acetate or copper sulphate be used as a treatment. But his suggestions were adopted very slowly by the grain farmers of Europe, and it was not until the middle of the nineteenth century that seed treatment with copper sulphate became general.

The next step towards the complete understanding of covered smut's life history came about when the Tulasnes, Louis and Charles, with more powerful microscopes, were able to see the complete germination of the bunt fungus. In 1847, the Tulasnes saw that instead of simple "onion leaf" plumes, the sharp-pointed outgrowths from the germinating bunt spores were joined together in the shape of little capital H's. They saw that these, in turn, germinated into secondary spores. It was largely from these secondary spores that infection threads reached blindly for the soft tissues of the germinating wheat seed.

What was more, the Tulasne brothers verified Mathieu Tillet's hypothesis made a century before, that bunt—*la carie*—was a distinct and different disease from loose smut of wheat. They did what was fitting. They created a new genus for the bunt fungus, calling this species *Tilletia caries* in honour of the careful and ingenious Monsieur M. Tillet. Later another species of the fungus *T. foetida* was found to cause bunt, also.

Man has grown wheat, oats, barley, and rye for many centuries, and from the earliest times the smut fungus stuck as close to the grain as man's own parasite, the ubiquitous head louse, stuck to the pate of the peasant farmer himself. Of course, long ago the disease and the methods that would control it were unknown. The first inkling that this plant parasite could be controlled came much later.

Until late in the last century, the farmer sowed his wheat by broadcasting. With the tempo of his walk and the measured rhythm of his hands, he flung the seed of his grain evenly over his fields. Sometimes his hands became covered with a black and stinking dust that came from the seed grain. The wheat came up green and lush, but at harvest time some of the stalks did not yield hard kernels of grain; the stalks held shrunken black "kernels" of the same stinking dust that had dirtied his hands at sowing. As a defence, the farmer began to clean his seed grain, first by simply washing the grain or soaking it in water. Later he used any liquid that was common and handy, often mixing various other substances with it. Farmers near the sea tried saltwater. Elsewhere, some used limewater or lime slurry, with little or no results. To farmers of the Middle Ages, urine seemed potent as a steep for their smutty seed grain. Some favoured horse urine because, after the liquid stands for a few hours, it becomes ammoniacal and the farmers believed that what could bring tears to their eyes was strong enough to kill anything. These crude steeps were quite ineffective, but the method proved to be correct.

The practice recommended by Prévost of steeping the grain in a copper salt solution was continued from 1850 to about 1900. However, this treatment was often injurious for, when carelessly used, it killed the wheat embryo of the seed as well as the smut spores. But the chemists soon found better and safer chemicals and, about 1900, formaldehyde, a liquid treatment, supplanted the copper sulphate steep.

Various chemicals in the form of dusts came into general use during the 1930's. Some of these were made of mercury compounds and were either mechanical dusts formed by grinding solid compounds or colloidal ones, formed chemically. These dusts did not require water as a carrier or a spreading agent, but they were very poisonous and great care had to be taken in treating the seed. Since 1950 new chemicals, hexachlorobenzene being one, have been tested and found very effective. The chemists and biochemists are continuing to find new and promising fungicides in man's fight against covered smut.

This general method of applying chemicals to the surface of the bodies of plants, their fruits, or their seeds, to inhibit or poison the germinating spores of the parasitic fungi, is known to plant pathologists as topical chemotherapy. The results of this method have been exceptionally good. These chemical dusts and sprays have saved millions of tons of foodstuffs for the hungry world by killing the disease-causing parasites in their inoculation stage.

However, no better method for the partial control of the loose smuts of wheat and barley has been found than the one the Danish plant pathologist Jensen discovered in 1888. This is a hot water soak requiring closely controlled temperatures to be effective. The warm wetting of the grain induces the tissues of the kernel to produce hormones that offer resistance to the disease.

The reason for the failure to find any chemical control of loose smuts is that these fungi do not survive the winter in the form of tiny spores clinging to the outside of the rough seed coat of the grain. Their spores were already formed before the wheat or barley plant flowered, and they had infected the blossom and penetrated the tissues of the developing seed at that time. Long before harvest the mycelium of the loose smut fungus is already safe from chemical attack inside and among the cells of the grain kernels. Any chemical dust or steep strong enough to kill the fungus would necessarily kill the embryo of the seed.

Corn smut is even more difficult to control. Its spores remain protected and alive from one season to the next in the soil or in infested corn debris left carelessly in the fields. Under favourable summer conditions they germinate, forming tiny, detachable fruiting structures, or sporidia. These sporidia are blown away by the wind and lodge on young corn plants, causing local infections. Because chemical spraying with Bordeaux mixture is too expensive for the ordinary corn farmer, the only practical solution is crop rotation.

When M. Tillet experimented in the French wheat fields two centuries ago, he recognized two smuts, covered and loose. In 1960 the plant pathologists had identified well over a thousand species of smut attacking seed plants. Of these, over six hundred species feast on the grasses and cereals of the world—flower smuts, stem smuts, leaf smuts, root smuts. However, since about 75 per cent of man's food energy comes from the cereals, we are most interested in smuts that attack these food plants.

The worst smut of all is bunt, or covered smut of wheat, which is the most serious continuing menace to wheat crops. Common smut of corn is also a very destructive disease. The loose smuts of oats and barley come third and fourth in order of menace.

Notwithstanding the lack of information in the writings of the ancients, the modern plant pathologists are sure that the smuts, and especially the covered smuts, have plagued man in his attempts to grow grain from the time that agriculture began, probably thousands of years before he even learned to write. One can but imagine the effects on primitive farmers when a third or a half or more of their crop turned from sound golden grain to stinking bunt balls.

The clouds of bunt spores rising above the pounding flails of the sweating winnowers would have saturated the air with the deadly inoculum. The very soil of some of these ancient valley farms must have been seeded by the spore showers during the harvests. Every year the loss to the farmers' grain crops must have been high and, periodically, whenever conditions were very favourable, disastrous.

Smut—hunger—migration—war. That was the usual sequence. Just as surely as the rats and the other vermin ate up the grain crops, so did the smut. And when hunger faced the tribe, the old men knew but one remedy: a move to new land in another valley. If that valley was inhabited, war was inevitable. Even if they overcame the enemy or if the land was uninhabited, the invaders did not always win for they often carried the disease with them to contaminate the new land, or the soil of the new valley was as polluted with smut spores as the soil they had left.

All these scientific guesses regarding prehistorical events cannot be verified. Not one bit of proof has been found by archaeologists. However, because it is reasonable to assume that hunger drives people to a source of food, large crop losses would be at least a factor influencing migrations of ancient tribes. There is historical evidence that wave after wave of migrating tribes spread over Western Europe from the Caucasus regions, the source of most of our common grains as well as of most of the people of the Western world. Although historians generally attribute these migrations primarily to population pressures, peoples might well have been driven from their land by the hunger caused by smut.

And what of the Middle Ages? At this time society was more stable. Feudalism, although it gave the people little security from hunger, did bind them to their lord's land. No doubt the seigneur was heartsore if famine carried off many of his serfs, but he held fast to his lands and his cattle. His mercenaries beat back any starving migrants who might strive to move into his seigneury by force. During those centuries, smut may have acted as one limiting factor in any incipient population explosion.

Plant pathologists now think the smuts were and still are second only to the rusts as cereal-crop destroyers. But will they remain in second place? Despite our present knowledge of chemical preventives, bunt even now consumes as much as 50 per cent of the wheat in parts of such modern grain-producing countries as the United States, attacking winter wheat much more severely than the spring varieties. In the Pacific Northwest, across hundreds of miles of winter-wheat country in Washington and Oregon and Idaho, the crop is especially susceptible to attacks of this cereal-fungus disease. Losses in these states during the early 1950's were especially heavy, averaging in excess of five million dollars per year. Infestation often ranged from 30 to 50 per cent, and the combine harvesters, in their circuits of the fields, raised clouds of stinking bunt spores that rivalled the smoke screens of the great World Wars. These countless billions of spores swept over the countryside in smut showers that resulted in the infestation of the fallow fields for hundreds of miles around. The soil was saturated with these bunt spores, and there they lurked in safety until the autumn sowing. No chemical seed treatment of the time could protect the delicate wheat seedlings from these massive attacks of bunt. Year after year the farmers lost their battles against covered smut. But they hung on in their determination not to abandon their farms to the fungus.

True, the situation in the fifties was better than in the old days back before World War I, when bunt was even more destructive. Then the losses rose to over ten million bushels, and infestation in some fields ran to a shocking 85 per cent. Bunt spores chocked the harvesters and filled the interiors of the threshing machines with spore and air mixtures that were exploded by the static electricity from the fast-running belts, or by the sparks struck by little stones against the steel teeth of the whirling threshing cylinders. The resulting fires burned the threshing machines and often the threshed grain. Occasionally, these fires spread in the stubble and destroyed the shocked grain in surrounding fields. Although losses caused by smut explosions and fires came to a small fraction of the total, they were spectacular and disastrous to the individual owners. With today's harvesting methods, this danger has diminished.

Losses from bunt in the United States were not confined to the Pacific Northwest. The winter-wheat belt in the Midwest has also suffered. Nationwide, in the past, the loss from bunt has averaged about 3 per cent in the winter-wheat regions. That loss translated into dollars means that the winter-wheat farmers of the United States realize about five million dollars less annually than they would if bunt could be brought under perfect control.

Most of the bread wheats of the world are the hard spring wheats which are not as susceptible to covered smut as the winter wheats. For this reason, the fields producing these hard bread wheats on the North Central Plains of the United States and in the prairie provinces of Canada have suffered minimal losses to this disease, especially since formaldehyde became popular as a seed-treating chemical. The winter-wheat countries of the world, however, continue to pay tolls to bunt. Altogether the losses from bunt and other cereal smuts throughout the world probably total 250 to 500 million bushels of grain annually.

Despite the losses from the smuts and other diseases, there are surpluses of cereals stored in the granaries of the grain-producing countries of the world. But these surpluses result only from faulty distribution. If every human being of the three thousand million on earth had the food calories necessary to prevent slow starvation, there would not be a single kernel of grain left over from year to year. It becomes ever more important, as the population increases, to cut the world's grain losses to still lower levels. Because grains are the most easily stored foods of all, it is imperative to stockpile them in the "fat years" of the present to alleviate the suffering in the "lean years" that will inevitably come.

One would scarcely expect to get a delightfully edible product from a plant disease as dirty and destructive as smut. But long ago, somewhere in France or in England, it is not known which, a baker found himself with a few sackfuls of flour that had been milled from smutty grist. He tried to make bread from it, but the smutty flour made dirty looking loaves, and, what was worse, the dead-fish stench of bunt that came from the hot oven sent his customers away holding their noses. The baker threw his dirty flour aside as worthless until one day the solution of his problem came to him. If he made little cakes sweetened with treacle, the dark molasses would mask the colour of the smutted flour. And if he could get rid of the rotten taste, he might be able to sell the whole mess to his unsuspecting customers. Remembering a strange condiment that had been newly shipped from Cathay, a spice that was both pungent and hot to the tongue, the baker planned a recipe, mixed the dough, and baked the little cakes. And so gingersnaps were discovered. Generations of happy little boys and girls, munching hot gingerbread, successor to the gingersnap, and reciting,

Run, run as fast as you can,
You can't catch me—
I'm the Gingerbread man,

have never suspected that this popular cake was invented solely to save a medieval baker some money during a bad smut year.

Smut claims a steady annual toll of about 2 per cent of the world's entire grain harvest. Since the annual wheat harvest amounts to about ten thousand million bushels, this loss deprives the hungry of about twelve thousand million loaves of bread each year. Obviously, in the face of such staggering losses, man must continue to seek ways of combating his age-old enemy. In the past, several resistant wheats have been selected or created. Each was satisfactory for a time, until infected by a new smut mutant. Smut grown in a laboratory on a suitable nutrient jelly called "agar" often develops as many as four or five mutations on a single plate of the nutrient. And there is no doubt that mutants are formed just as readily in their natural habitat, the succulent tissues of the host plant. So far it seems that the development of each new resistant variety is but one phase in a perpetual contest between man and fungus.

Lately, an interesting new approach to plant diseases has been developed by plant pathologists who realized that the sprays controlling localized attacks on the plant were quite inadequate in dealing with deep-seated, systemic diseases. The plant pathologists began to search for a specific chemical that would travel through the circulatory tissues of the sick plants to wherever the disease pathogen was destroying the plant tissues.

Ehrlich had found Salvarsan after testing 606 likely substances in his search for a chemical to cure human syphilis. This mercurial compound would travel through the bloodstream to wherever the deadly corkscrew spirochetes were destroying human tissue and, without harming the host tissue, would poison the germs. In their efforts to apply Ehrlich's hypothesis to plant diseases, the plant pathologists began experimenting with hundreds of thousands of compounds. They wanted chemicals that would act like 606, that could be put into the body of the plant through the leaves by a foliage spray, into the root system from the soil or, in larger plants, directly into the stems by injections into the circulatory tissues. They have been moderately successful in this systemic chemotherapy, and it is quite conceivable that eventually a systemic chemical or drug will be found that will destroy the grain smuts in the hosts' tissues, conserving additional quantities of grain that man needs so desperately to keep back famine.

Meanwhile, man's best defence seems to lie in growing grain and hay or grain and root crops in alternate years. This solution is difficult where climate and soil favour but one type of crop; it is impossible where grain farmers themselves, faced with adopting mixed farming, prove more resistant than the grains.

4 The Great Irish Potato Famine and After

POTATO BLIGHT

Every time man has succeeded in building a lasting civilization, he has first secured a staple food. Wandering herdsmen, nomadic hunters, or mere gatherers of food had to be ever watchful for the next meal and so had little leisure to develop a great culture. All great civilizations were built by men who had a fixed place to live and whose staple food was of cultivated plant origin. For example, the civilizations of Southeast Asia rest solidly on rice, those of the Mediterranean on dry-land grain. Farther north in Western Europe, most of the people in the Middle Ages were grain farmers; rye was the staple cereal. The Mayan and Aztec civilizations of Central America and Mexico were corn cultures.

Thousands of years ago, the pre-Inca people pushed their way up and over the inner ranges of the Andes from the jungle of the Amazon basin. They found, there in the high valleys and on the cold plateaux that lay well above the ten-thousand foot level, a plant worthy of cultivation. This plant had stems both above and below the ground level. On the underground stems were swollen lumps—we call them tubers—rich in proteins and carbohydrates. On this plant, propagated by the Indians of the Andean valleys, the great Inca civilization was based. The farming men dug the soil with their *tagllas*, a long, narrow, pointed stick similar to the one used by the Irish hundreds of years later. Their women planted the tubers of the plant which they called "papas", but which we call potatoes. Thus, secure in their mountains, the people of the Inca empire learned to keep themselves supplied with this good and surprisingly complete food. The potato, with its proteins, carbohydrates, and vitamins, was the source of the energy that built their astounding civilization. When the conquistadores smashed the Inca empire, they carried off all the things they thought to be of value—gold, silver, jewels. But the most valuable treasure of all they did not bother to record.

The introduction of the potato to Europe was apparently accidental. It is known that sailors of the Spanish galleons used the raw or dried tubers as provisions on their long voyages back home, but it is not known how the tubers were able to survive the hot, slow voyage through the Spanish Main in the lumbering galleons.

However, many separate plantings seem to have been made from about 1570 onwards, first in Spain, then in France and Italy.

The cultivation of this strange plant spread slowly through the rest of Europe, however. For nearly two centuries the peasants were too hag-ridden by ② superstition and too ③ stolid in their resistance against new foods to accept the potato. There is a story, hard to believe, that many people tried to eat the bitter green berries that are its fruit and then pronounced the whole plant worthless.

Other people, knowing through the newly formulated classifications of plants by the famous taxonomist, Linnaeus, that the New World potatoes were directly related to the poisonous Old World plant, the nightshade, spread the belief that the new plant must be poisonous, too. Others, listening to the witches and alchemists, ascribed occult and special powers to the potato tubers. It was widely believed that eating the potatoes caused great windiness of the bowels, and many believed this new food to be an aphrodisiac. Variations of the phrase, "And eating of these roots doth excite Venus and increaseth lust", are seen frequently in the writings of the seventeenth century.

So for one reason or another, the Europeans clung to their rye bread on the continent and to their oatmeal in Scotland. But in the latter part of the eighteenth century, when the population increased and the smutted and rusted grains often did not supply sufficient food, the people were forced to look for a more reliable source of food, and the potato came into its own. On the high, cold plateaux of Spain, in the dank, flat lands of Germany and Poland, and in the soggy bogs of Ireland, this remarkable food plant flourished and yielded tons of harvest compared with the pounds of "seed" that went into the ground each spring.

The Irish say, in what amounts almost to a legend, for there is little or no proof from historical research, that it was Sir Walter Raleigh who first brought the "spuds" and "lumpers" to the "Ould Sod". At any rate, here was a crop that appealed to the quick wit and intelligence of the Irish and helped to ease the peculiar condition in which they found themselves in the eighteenth century.

These Celtic people, who were being squeezed by the exorbitant rents of their absentee English landlords, often resisted. Then the hated soldiers, minions of the English, invaded the Irish farmsteads, burned the grain, and even drove away the poor family's pig, too. But the Irish could now keep a hidden supply of food. The very nature of the new plant with its underground tubers made this possible. The Irish people did not plant their potatoes in rows. They made long, narrow beds of soil that were raised two or three feet above the surrounding ground. This plot was called a lazybed and it might be six to eight feet wide and a hundred feet long. In it the tubers were planted thickly and helter-skelter. The raised lazybed method allowed the Irish farmers to hide their spuds in the middle of the bogs where the English soldiers either didn't suspect or didn't care to look. If need be, the potatoes could be left in the lazybed where they kept very well through the cold winter weather. This crop, stored in the soil itself, was often the only source of food the Irish had in their times of trouble.

So, all over Ireland in the early nineteenth century, if you wandered into the garden of Sean O'Reilly, Tim Gallagher, or Matt Slavin, you would find the lush, dark green foliage of the ancient plant that had been the foundation of the great Inca empire. Everybody in Ireland—that is, everybody except those few people of quality rich enough to buy bread and bacon—actually lived and thrived on this single food—the potato.

Day after day the peasants dug the potatoes from their lazybeds until the terrible year of 1845. In one disastrous month of that summer the potato plants all over Europe sickened and the tubers rotted and the poor people began to go to bed hungry.

What caused the disease in the lazybeds of Ireland and in all the potato fields of Northern Europe? That was the great question. Indeed, the Irish cottiers, the English farmers, and the peasants of Europe wondered, as well as the botanists and the people in high places.

Had the "little people" started it, as the superstitious ones believed? Was the land run down, as others thought? Some believed that the Devil had brought the disease, and so they sprinkled their spuds and lumpers with holy water to drive the Evil One away. Others said it was God's punishment for the waste of the bountiful harvest of preceding years. Had they not in the past, sinfully flouting the Almighty, thrown thousands, even millions, of surplus potatoes into the ditches and the bogs to rot?

One man said, and many others were inclined to believe him, that the puffing, hooting locomotives that thundered up and down the countryside at the unholy speed of twenty miles an hour were discharging electricity into the air. Even the scientists theorized that this static electricity might be capable of producing almost anything. Still others stated that the vapours from the active volcanoes of the world were poisoning their potatoes. A few believed that repeatedly planting "seed" selected from the previous year's crop weakened the plants and reduced the yield. When ultra-microscopic viruses were discovered to be passing from one potato crop to the next, some basis for this hypothesis was proved correct; but viruses were not responsible for the epidemic of the 1840's.

Then there was Disease, that mysterious condition that came quietly and unheralded to man, beast, and plant. Disease, they said, was everywhere and existed in many forms. Surely then, the blight of potatoes was but a new form of that many-headed monster—Disease.

Then there was the weather! The spring of 1845 had been warm and pleasant. The summer had been normal, but suddenly the weather had changed. The temperature dropped as much as seven degrees below normal and the cold rains began. For weeks no one saw the sun and the people huddled, in Ireland at least, by the warmth of their peat fires. There was no way for the potato plants to escape the chilling drizzle. People thought that since cold and wet weather brought Disease to themselves and their animals, the cold wet weather also brought Disease to the potato. The grains weathered that miserable summer, and good yields were brought in from the Irish harvest fields. No one tried to explain why the weather and Disease had not devastated the cereal crops.

The weather, Disease, weak potatoes, God's punishment, the Devil's handiwork—these were the causes of the potato blight, depending upon who was talking and who was listening.

Whatever the cause, the people of Western Europe were face to face, in that year of 1845, with their worst enemy of the century. This disease of the potatoes threatened them with hunger and famine more widespread than the ravages of Napoleon's armies. And with the famine, the fevers and plagues would come as they always had; and "Old Man of Death" would ride up and down the land.

Dr. John Lindley, professor of botany and editor of the *Gardeners' Chronicle and Agricultural Gazette* which was published in London, believed that the wet had caused the trouble. He argued that the plants had been growing at a great rate while the weather was normal. Then had come the deluge of rain. The potatoes, strong and vigorous, had sucked up the water through their roots until they were sodden and, not being able to get rid of the excess, had taken the dropsy and their tissues had rotted away.

One of the most bizarre and revolutionary theories came from the Reverend Dr. Miles J. Berkeley, whose hobby of collecting and studying fungi had made him an outstanding authority, in England at least, in this field. As he looked through his microscope at a leaf from an infected potato plant, he saw that it was covered with a mould similar to what he had seen on sick onions. But he was convinced that this was a new and different mould and that it was killing the potato plants in all of Ireland.

A few days later Dr. Berkeley received a letter from his old friend, Dr. C. Montagne, in Paris. This letter contained specimens and drawings of the fungus that was on the dying potatoes in Europe. A glance was all that Dr. Berkeley needed to see it was the same fungus that he had seen himself in England. Now he understood. This new fungus was a parasite, and it alone was causing the terrible destruction of the potatoes.

He set forth his new hypothesis in a letter to the *Gardeners' Chronicle.* If he had expected the news to burst like a bombshell, he was disappointed. Dr. Lindley published the letter, but Dr. Berkeley's startling hypothesis aroused no excitement among the learned readers. Dr. Berkeley had merely submitted his hypothesis with no supporting proof whatever.

The new fungus was on the potatoes; there was no doubt of that. Anyone with a good microscope and the skill to use it could see the fungal threads packed together in a whitish felt on the surface of the leaves or in the tissues of the diseased plant. Dr. Lindley patiently pointed out to Dr. Berkeley that the new fungus was simply acting as a scavenger. It was a saprophyte and, like the vultures of the animal world, it was gorging itself on the dead potato tissues that had been killed by the wet or, as some would have it, by Disease.

The learned and gentle argument dragged on in the late forties and through the fifties. Not until 1861 did Anton De Bary, the eager, indefatigable German, settle the matter once and for all. He selected two groups of healthy potatoes and subjected them to the same conditions of cold and humidity. The plants of one group, however, he dusted with the "late blight" spores, so-called because the plants were blasted in the late summer, but he guarded the other group so well that no spores could lodge on their leaves. In a few days he had the answer. The spore-dusted plants were sick. In a few more days they were a black and rotten mass. The uninfected plants were growing strong and healthy. Here was proof for the Irish, the Dutch, and the whole world to see: this fungus was a parasite, and it did cause the late blight of potatoes.

A well-chosen scientific name should describe some distinguishing physical characteristic of the new organism. Despite the fact that De Bary's choice of name did not do this, an omission that aroused some criticism, it was his *Phytophthora infestans*, "the terrible plant destroyer", that other botanists finally accepted in recognition of his work. Regardless of its lack of precision, the name will forever recall the disasters that the late blight fungus brought to mankind.

As De Bary found, the infection spreads from plant to plant, field to field, and country to country in the form of tiny one-celled, egg-shaped spores. These tiny cells ride the stormy winds. Rain splashes them onto the leaves and drives them into the soil. The spores that fall on the leaves in the rain droplets germinate in two ways. Sometimes they send out long, tubelike threads. Sometimes they swell and break open, releasing a swarm of swimming spores that scatter, settle down, then send out their own little germ tubes. These tubes enter the leaf in two ways, some entering through the stomata, the breathing pores, and others by a chemical enzymic action that dissolves the protective epidermis, the protective surface layer of cells. Once inside the leaf, the parasite spreads like wildfire. Its threads, or hyphae, divide and wind like snakes along the tiny air spaces in the leaf, plunging thumblike haustoria, or suckers, into the living cells, and "drinking" the rich, nourishing sap of the potato plant. These infected cells, being devoured from within, die from malnutrition and from the toxins released by the fungus.

At this time the fungus reaches the peak of its vitality and sends out fruiting structures through the stomata on the underside of the dying leaf. The fruiting structures hang from the under epidermis, sparsely branched, resembling upside-down Christmas trees with egg-shaped spores* at the tips of the branches. Each leaf has hundreds of thousands of stomata, and one to five fruiting structures, each bearing several spores, hang from each stomata. Therefore, the total possible number of spores from each infected potato leaf could run well into millions; and since each spore is so exceedingly small that five hundred of them could rest on the period at the end of this sentence, they are widely disseminated by wind. From germinating spore to new spore production only a few days elapse.

Thus the short spore cycle and the tremendous numbers of spores produced, together with the quick scattering of these spores by the wind, explain the calamitous spread of this blight from plant to plant, and even country to country if the weather is wet and cold in the late summer.

One mystery remained unsolved. Where and how did the late-blight fungus pass the winter? Did it live in the soil? If it did, how could it withstand the frost? Did it produce thick-walled spores for that purpose? No one could say. No one had found the *Phytophthora infestans* fungus producing any spores other than the egg-shaped ones. They were certainly too delicate to stand freezing; even in summer they lived for only a week or two. It was soon proved that the hyphae could not live through winter anywhere but in potato tissue.

What part of the potato was kept through the winter? Only the tuber itself. It was no trick at all to find out whether the planting of infected tubers perpetuated the late-blight fungus. Observation showed that some of the plants from such infected seed were blighted. The fungus grew upwards through the stem, and soon the underside of the leaves was covered with the spore-bearing structures. Even though each infected plant might produce millions of spores, this fact still did not explain the epidemic that struck all the plants in a field, sometimes in a single night, as if the field had been dusted, not with millions but with countless billions of spores at one time.

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* The fruiting structures are called conidiophores—a word derived from two Greek roots meaning "dust bearers". The spores are called conidiospores.

Another unsolved mystery involved the growth site during the cold spring weather. Did the fungus have some sheltered place, some natural hotbed, where it developed its spores? Years were to pass before the answer was found.

The common practice has always been to sort the potato tubers in the early spring, keeping the sound ones for seed and discarding any that show signs of rot—often discarding them carelessly in cull heaps. The culled tubers sprout in the heaps and often, even before the potato fields are planted, the mounds, warmed by the spring sun, are green with young potato plants. If just one of the culls gives rise to a blighted potato, in but a few days or weeks all the plants growing from the cull heap are infected, and the heap becomes a focus of infection for the potato fields of the countryside, particularly in muggy weather, with heavy dews at night, and drizzly days.

In at least two of the most disastrous epidemics of late blight, the preceding year's potato crop had been phenomenally large, yielding far more potatoes than could be used as food for human beings or the livestock. The surplus was stored, but no storage system yet devised has been perfect; there has never been a year when a few blighted potatoes were not stored with the sound ones. Thus, after those record years, the rot of the late blight proceeded slowly in storage, and the infected tubers were discarded the next spring with the surplus healthy ones, dotting the land, in the springs of 1845 and 1846, with great heaps of cull potatoes. The terrible plant destroyer was ready. The spring weather in those years was warm; the summers were wet. The potatoes rotted almost overnight, it seemed, and famine, the fourth rider of the Apocalypse, rode up and down the land claiming his victims.

It is difficult today to understand the reasons for the Irish famine. True, a meal is rarely complete without potatoes in one form or another. But to starve without them! Surely the Irish must have raised meat, wheat, oats, turnips, and the like. They did. Then why starve?

In the light of the political and economic conditions of Ireland in the 1840's, the picture clears. The Irish had had, for two centuries, little or no control over their own affairs. The land was not theirs; practically all of Ireland was owned by the English. But this was not a new situation. Ever since the time of Henry II in the twelfth century, Ireland had been periodically carved into estates and granted to the followers of the English rulers. However, descendants of these lords and of their soldiers became Irish through intermarriage—often more Irish than the people they had tried to subdue—and the struggle went on for centuries. After Cromwell, the greater part of Ireland passed into the hands of that dictator's English soldiers and remained there.

Thus the economic decline of Ireland had begun two hundred years before the potato famine. The English parliament, which of course controlled Ireland, had deliberately crushed Irish commerce and industries by forbidding export from the island. Finally, after the expiration of the Irish tariffs in 1826, the Irish manufacturers and merchants, unable to meet English competition, withdrew their capital from trade and bought land.

The land was the thing. Everyone wanted land. Everyone needed land. Certainly there was little work for anyone without it. A man might rent a hundred acres from the agent of the absentee landlord. Then he would subrent most or all of it in five-acre lots at higher rates. These plots were cut into still smaller portions and rented again at still higher rates. At the bottom of the economic heap were three million farm labourers who might have a quarter of an acre each upon which to grow enough to feed their families.

Now a quarter of an acre is a very small piece of land. On so small a plot, a bare minimum could be set aside for housing. Consequently, the poor labourer and his family lived in a tiny mud cottage with neither floor nor windows, only a door, and a hole in the roof to let out the smoke of the turf fire. There was never enough room for the man's wife and children, but what space they had was shared with the family pig, worth four pounds in English money, more than half the value of his labour for the year—if he was lucky enough to find work. Two-thirds of his yearly income of seven pounds went for the rent of his hut and his little garden of "praties". These potatoes, eight or ten pounds per person per day, were the sole item of food for him and his family. They dared not eat the pig; it must be sold to get money for the rent if work was slack.

Thus, the cottier lived in extreme poverty. Added to the hardship of exorbitant rents was the discharging of debts in which many improvident cottiers became involved. Usury itself was prohibited by law, but there was an easy way to get into grievous money trouble. Anyone who needed ready cash could go to a "gombeen" man who sold a sack of meal worth twelve shillings for a one-pound IOU. Then, without laying a hand on the sack, the borrower could sell it back to the "gombeen" man for ten shillings cash. Interest had to be paid, of course. And when the poor man needed more money, then he could easily buy another sack of meal for another one-pound IOU. With equal ease he could mire his family in debt.

The phenomenal fecundity of the Irish in the first half of the nineteenth century doubled the population of that country. Some researchers in group biology have found evidence that a species, when it first feels the pinch of food deficiency and the effects of overcrowding, instinctively begins to reproduce at a higher rate. These researchers think that, because man is an animal species, he will react to the same stimuli in the same way. Others believe that whenever there is a new source of food, such as the potato in Ireland, the rate of reproduction increases. Whatever the reason, the population of Ireland from 1800 to 1845 increased from four million to eight million, and Ireland became one of the most densely populated countries in Europe.

When the children reached the age of twelve or so, they were put out to work to increase the family income. A big family was therefore viewed as a blessing, and every year the population increased by nearly two hundred thousand people, half of whom depended directly or indirectly on the potato for their very lives.

Absentee landlords who visited their estates in Ireland during the 1840's were amazed at the large numbers of paupers living in filth and rags. Some enlightened landlords made plans to clear away the mud cottages and stone walls so that small holdings could be combined into large fields suitable for grain or mixed farming. But they met with only sullen resentment or shillelaghs from the people they were trying to help. Although the Irish cottiers—at least some of them—would get steady work if such plans were put into effect, they did not dare to give up their potato plots, the source of the little food they had. The well-meaning landlords had to abandon their plans and leave the Irish to work out their own solution.

When the first rumours of the new and terrible potato disease ran through Ireland, the cottiers, who had given little attention to the wilted tops, dug nervously to see the condition of their tubers. Many were rotten already. When the sound tubers they did dig up rotted away in the storage pits, their worry changed to despair. In the districts worst hit by the potato blight in 1845, the cottiers and their families resifted the potato ground and searched the edges of the ditches and the bogs for stray tubers. They washed away the rotted parts and grated what was left into potato flour. A family of ten needed a ton of potatoes per month to survive, and the few sound potatoes they found or grated up left them weak and hungry. Children searched the woods for nuts, berries, and holly fruit. They dug for fern and dandelion roots. They ate the leaves and the bark of trees. They groped for eels and trout in the streams and trudged for many, many miles to scrape limpets, mussels, and seaweed from the rocks on the shore. Many died from the poisonous effects of these strange foods, but hunger drove the survivors on and on in their pitiful search. They bled the livestock on the hoof and drank the blood or made blood puddings. Often they even ate the pig.

A few of the landlords forgave them their rent or shared what little surplus food they had, but most of the extra grain and livestock was sold abroad. Even the more fortunate cottiers who managed to harvest a few hundred pounds of tubers found that after they had paid their rent and the interest on their debts to the "gombeen" men, they were destitute. They had no money to buy food. Many of the landowners themselves were on the verge of bankruptcy. But still the provision carts, piled high with sacks of grain, rumbled along the roads to the export houses. Great flocks of sheep, cattle, and pigs were driven to market by the landlords' agents, and the people, weeping and wailing from hunger, watched them go.

News of the disaster in Ireland stirred the government in London. The one hundred and five Irish members of the Union Parliament pleaded for their people. As early as October, 1845, Dr. John Lindley was a member of a government commission sent to Ireland to suggest ways and means of saving whatever few potatoes remained sound.

A poor law system, whereby relief could be given to inmates of the country's workhouses, did exist in Ireland at this time. But the government realized early that in the face of this imminent crisis the workhouses would be entirely inadequate. What was there to do? Sir Robert Peel, who was Prime Minister at that time, decided on a bold plan of relief that violated the simplest economic principles—so said the experts! The Irish economy must be left alone, they said. Any tampering with it by giving out money and food would upset the delicate balance between supply and demand, and ruin would surely result. They, the experts, simply would not realize that ruin of the most grievous kind had already come to the Irish people.

In spite of the warnings of the economists, Sir Robert Peel, in November, 1845, set up an Irish Relief Commission which bought American maize, or corn. By February, 1846, more than a dozen food depots had been set up in Irish seaports, and from March onwards, corn was sold from them, six hundred tons weekly in the Cork depot alone. In order to buy the corn, or Peel's brimstone, as the critics called it, the Irish labourers were given government relief work on dock repairs, road work, and drainage. Altogether the government spent the then huge sum of three quarters of a million pounds in grants or loans. The Irish people got through the 1845–46 season without too much privation, and prepared for the planting season of 1846 with hearts full of hope.

The spring was fair, the lumpers sprouted, and once again the fields of Ireland were as green as emerald. The crops were luxuriant in May, but early in June the rains came again. With the rains came worry, then anxiety and, by the middle of July, despair. There was scarcely one sound potato in all of Ireland! By early autumn the cottiers were once again scrabbling in the fields and in the woods and along the streams and roads and all the way down to the sea for scraps of anything that might serve as food.

The government, meanwhile, had changed from Tory to Whig. Sir Robert Peel was out of office, but the relief schemes which operated under his administration continued for a few months in almost every county in Ireland. These emergency measures could not cope with a disaster so widespread and devastating, and the first death from starvation was recorded in August, 1846. The death rate from famine began to rise, and as it mounted the people sank more deeply into despair. Those who had the strength still wandered the countryside in search of food or alms or made their way to any workhouse they could find which was not already filled to overflowing. The weak could only huddle in the straw on their cabin floor with a dirty blanket over them. Death came faster to the old and the very young, but many strong fathers and mothers sacrificed themselves by giving their share of food to their little ones.

Hunger would have been enough to endure, but with it came three of mankind's most terrible diseases, dysentery, typhus, and relapsing fever. The crowded workhouses became hotbeds of disease. The soup kitchens that daily served as many as three million persons with stir-about (a cornmeal gruel), and the road-work gangs that employed as many as seven hundred thousand brought the people together from far and near. The lice, carriers of the diseases, crawled from person to person as they huddled together in their sleeping quarters. And the weakened people fell easy victims to the fevers that the vermin spread. Thousands of people died by the roadside. Starving children gnawed away the breasts of their dead mothers, and sometimes crazed mothers chewed the flesh of their dead or dying children. The horror that filled Irish lives is memorialized even now in the names of fields, roads, burial grounds, and in folklore.

Although many of the healthy men and women stayed to care for the sick, others fled the country while they and their families were still well and strong, and the stream of emigration, once started, went on for years. In ten years Ireland's population dropped by three million people —one million dead and two million emigrated to the United States, Canada and other parts of the British Empire.

This failure of the potato crop in Ireland had a far-reaching effect on English history. Since the Napoleonic Wars the Corn Laws had imposed a heavy tax on grains imported into Great Britain, protecting the landowners by keeping up the price of grain on the British market. The Whigs in Parliament had long argued that this tax should be removed so that the price of flour might be lowered to a level that the industrial workers could afford.

Sir Robert Peel, while still leader of the Tories, the landowners' own party, forced repeal of the Corn Laws after a most bitter debate in the British House of Commons. The Duke of Wellington summed up the reversal of Tory trade policy: "Rotten potatoes have done it all; they put Peel in his damned fright." However much it displeased the landed gentry, the abolition of the tax on imported grain appears to have been the first step towards the policy of free trade. With the abolition of import taxes on all goods, Great Britain became, during the last half of the nineteenth century, the mighty centre of trade for the whole world, a sort of clearing house for the earth's raw goods and manufactured products. The British mercantile fleet grew to be the greatest in the world in this same period, and Great Britain, because of her industrial and mercantile wealth, made secure her position as the dominant nation of the globe.

Altogether, the British government expended eight million pounds for relief in 1846, a monumental figure in that era of *laissez-faire*. True, most of that sum was held to be a loan to the Irish people, but only a small fraction of it was ever repaid. As a fact of history, this stands out as the first fairly successful effort made by the state to aid its starving people. Before this time the victims of famine had been forced to "root, hog, or die". Personal disaster had been treated as a man's own concern, or the concern of his family, but definitely not the responsibility of the state. Relief and aid to the poor were held to be matters for the local authorities.

Now, for the first time, a state whose government promoted the idea of individual rights and responsibilities, saw and accepted its responsibility to aid the individual. The first step was taken towards what we now call the welfare state—and rotten potatoes were the cause of it all!

Not only Great Britain felt the impact of the Irish potato famine and its aftermath; the New World was forever changed by the same events. The emigrants who set out on the six-weeks' journey to America in 1845 and early 1846 got away before the typhus and dysentery epidemics, and these early immigrants were processed through the quarantine areas quickly and settled in the new lands.

Between spring and autumn of 1846, however, conditions became much worse, and late in the year the immigration authorities of Canada and the United States were beginning to worry about the great number of ill and destitute people who were arriving. By 1847 the number of new arrivals had doubled. Every old tub that could sail carried the fleeing Irish. The boats were crammed full. Provisions for sanitation and comfort of the passengers were pitifully inadequate. The boats were mainly timber carriers whose owners were glad enough to take aboard a payload of Irish emigrants at three to five pounds a head because the ships usually sailed back to America without cargo and heavily ballasted. Now the captains packed their passengers in as the slavers had done. There was no place to cook, no place to put the sick. There were no proper latrines. The filth and the stench below decks was overpowering. Tragically, some who embarked to flee the epidemics at home carried incubating germs within their bodies. On the long journey across the North Atlantic the ships thus became hell-holes not only of filth and lice, but also of disease. One out of every twenty Irish refugees who embarked for the golden land of America was buried at sea.

Did the people of North America receive the survivors with open hearts? They did not! Fear and apprehension filled the immigration authorities and the general public. The quarantine areas were overcrowded in a week. Twelve thousand sick and weakened immigrants were existing in quarantine at Grosse Island in Quebec in May, 1848. A lucky few were provided with tents, but thousands more had to sleep exposed to the weather on the damp ground, and many died in misery. In desperation the authorities packed them off up to the St Lawrence, thus spreading their diseases all the way from Quebec to Toronto. Some people fled the towns when they heard that the miserable and dying immigrants were coming. For all their bitter antagonism towards the Irish immigrants, the Canadians were forced to build one monument to them, one that still stands—a great mound in Montreal that covers the bones of six thousand Irish dead.

Although conditions in the American ports were not as bad as those in Canada, outbreaks of typhus caused much fear and some hysteria. Considerable sums of money were expended by the Canadian and American governments for relief of the sick and destitute. Restrictive legislation and regulations in the two countries caused a shuttling of immigrants north to Canada in 1847 and south to the United States in 1848. But in spite of these difficulties and the lamentable conditions in Canada in 1847, a prodigious flow of Irish immigrants was absorbed. And there was a good deal of plain speaking and bad feeling about admitting multitudes of Irish paupers with their lice and their diseases.

After such an unhappy beginning, the Irish themselves made the great mistake of congregating in cities—in the slums, of course, for they were destitute and the incidence of tuberculosis among them increased. Once there, they stuck together through thick and thin, and their clannishness earned them still more dislike and distrust. As soon as they were enfranchised, they even voted en bloc. Many a Democratic candidate in the United States owed his success at the polls to the Irish vote. For some reason Irish Republicans were about as numerous as snakes in the "Ould Sod". So it came about that the Irish held the balance of power in government in many of the cities and states along the Atlantic seaboard, and still do.

Before the Irish came to America, the Roman Catholic Church held a very minor place in the spiritual life of the United States. But four out of five of the new immigrants were Roman Catholics, and the resulting rapid growth of Roman Catholicism has never been equalled in any other country in modern history. Roman Catholic churches, convents, orphanages, and hospitals were built by the hundreds and thousands, first in the cities of the eastern seaboard, and then westward as the Irish lifted themselves out of the slums of those big cities and spread their settlements—on the wrong side of the tracks it is true, for they were still poor and clannish—across the middle and western states. Religious bigotry today is on the wane, but in the 1850's the militant Protestant societies of this continent were all for the deportation of the "Micks".

It seems only one segment of the American people were really glad of this influx of the traditional "hewers of wood and drawers of water": the employers who needed manual labourers suddenly had an army of them. The Irish worked in the factories, on the railroad right-of-ways, anywhere they were needed. Paul Bunyan and the Swedes never would have been able to log the northern woods without them, and but for them the cowboys might still be trail herding their dogies from Texas to the northern stockyards. The ties and rails of the great continental railroads were carried westwards on the sturdy shoulders of the Tims and Micks in the 1850's and 1860's. Irish immigrants provided a vital and willing industrial force at a crucial period in American development.

During the fifteen years before the greatest internal struggle in all history, the Irish bent their backs and the fruits of their labour made the Union strong. When the Civil War broke out in 1861, the Northern states were far ahead of the Confederacy in industrial strength. Of course, when the fight started, many a boy from Erin's Isle laid down the axe or the shovel and took up the rifle. The Irish regiments in Blue did as well as any, and their war record helped to break the social barriers and move them, in the second generation, to the right side of the tracks.

One hundred and twenty years have passed since the great potato famine. Now the population of English-speaking North American numbers two hundred and twenty million, at least one in every ten of whom carries genes brought from the land of the shamrock. The descendants of the "shanty" Irish have also risen to very high places in the society of both Canada and the United States by their industry, intelligence, and a bit of Irish luck. In 1960, the Presidency of the United States, the most influential governmental position in the world west of Moscow, went to John Fitzgerald Kennedy, scion of two families that left Ireland to escape the famine in the 1840's—the Kennedys from Wexford County in South Ireland, and the Fitzgeralds, from Kerry, the land of the Killarney lakes and Tralee. And thousands of other men and women whose ancestors four or five generations ago were scrabbling in the dirt of Ireland for scraps of food, hold positions of influence in every land to which their forefathers immigrated.

The European continent slopes gently up from the Atlantic Ocean across France, Germany, Poland, and deep into Russia. The cold summer storms of the late 1840's that swept in from the west carried the late-blight spores with them. The potatoes rotted away in every country from Ireland to Russia. The peasants suffered, but there was no general famine because the agriculture of the Continent was far more diversified than that of Ireland. Nevertheless, with the disappearance of potatoes from the markets, in 1846–47, the price of bread and turnips rose; hunger became a reality, especially in the cities. And hunger, where it does not breed famine, breeds discontent.

In almost every country on the European mainland the poor demanded cheap food, and the peasants demanded ownership of the land. The yeast in this human ferment was the influence of the young political radicals, Kossuth, Mazzini, Lamartine; and beyond them rose the super-radicals, Engels Marx. and As in Ireland, the mainland radicals believed that if the disenfranchised people—99 per cent of the population in some European countries—could win the right to vote, their troubles would disappear and Europe would enter its Golden Age.

After the hungry winter of 1845–46, these radical leaders found growing sympathy for their ideas among the populace of the great cities. The unrest of the people heightened in 1848 when a severe depression, with its ruined businesses and unemployment, threatened the collapse of the economy of Western Europe. Hunger, poverty, and depression settled heavily on the people. As the brilliant young radical patriots spoke of freedom and reform, the masses listened with rumbling stomachs, and the news from Ireland added to their alarm. To quiet the peoples' restlessness, governments knew but one method—the use of nightsticks, guns, and bayonets. But insecurity and fear were not to be allayed by show of force; 1848 became the year of revolutions, unique in history. In that one year, brief yet tumultuous riots and revolts, as startling as a shower of meteors flashing into a black sky, flared in one capital city of Europe after another.

The prodding by radical leaders had been all that was needed. In Paris, Berlin, Vienna, indeed almost everywhere in Europe, barricades appeared in the streets. Monarchies fell; republics were born. New constitutions were granted; and liberal assemblies were instituted. The February revolution in Paris forced the abdication of Louis Philippe and the creation of the Second Republic. Kossuth demanded and got drastic reforms in Hungary. The Italians drove the Austrians from Milan. A liberal constitution was promulgated in Vienna and several dozen revolutions in the German states forced many changes in their constitutions. The political structure of a continent was affected and the change was due in part to the impact of the late blight fungus of potatoes.

Nor did 1848 see the end of *Phytophthora infestans* and the hardships it brought as it struck further blows at man's food supply. In 1872 late blight destroyed millions of bushels of tubers in England and Ireland. Again in 1879 the value of the crop lost in Ireland alone amounted to six million pounds sterling. Though Dr. John Lindley had learned as early as 1846 that downwind from the copper works in Swansea, Wales, the potato fields were green and healthy, not until late in the century was the efficacy of copper recognized. In 1885 the vine growers of France used Bordeaux mixture, made from copper sulphate and lime, on their mildewed grapes. By 1890, spraying the compound on potato plants was found to kill the germinating spores and the hyphae. Man was free at last from the spectre of potato famine.

In July of 1914, war broke out between Austria and Serbia, drawing their allies Germany and Russia, respectively, into what eventually became World War I. On August 3, Germany declared war on France, a Russian ally. The next morning, in order to outflank French fortifications and enter France at an unprotected part of her northern boundary, Germany invaded Belgium. Great Britain, committed by treaty (1829)—as were Russia, France, Prussia, and Austria—to guarantee Belgium neutrality and give assistance in case of attack, declared war on Germany. The most bloody war in history had begun.

The German army overran Belgium and, in spite of stiffening resistance, drove to within fifteen miles of Paris before the Kaiser's forces were pushed back and halted forty to sixty miles away. Both the German and Allied armies became stalemated in a trench warfare that persisted, under attack and counter-attack, for four years.

The Germans had hoped for a quick victory, but they were still confident of success. The stockpiles of war supplies were sufficient, and clever German chemists were successful in devising processes to make explosives from literally nothing more than air, water, and lard. Crops were phenomenally good. The 1915 potato crop was nearly three times the normal need. The German people were overjoyed. There would be lots of food and the livestock could be fattened on the surplus. And lots of potatoes would be left over to make into alcohol, which was very useful during wartime. There would be plenty of schnapps!

Government experts planned that all surplus potatoes were to be brought into the cities for storage before the bitter winter weather frosted the tubers. Decrees went out, and the people responded. No one, though, seemed to have a clear idea of how much storage space would be needed. The few warehouses that were not stacked with war goods would not begin to hold the tremendous surplus. Soon the warm basements of all the public buildings, including schools, were filled with potatoes. Farmers put tubers into the pig and cattle troughs. They sold them to the distilleries, but the price was low, almost too low to make it worthwhile to save potatoes. Why bother about them? The waste was immense.

For two or three months all went well. Then teachers and students noticed an unpleasant odour in the air. They did not have far to look. The school basements were full of sprouting, rotting potatoes. By early spring the stench was unbearable, and the teachers and students got "stench vacations" while the workmen hauled the putrid potatoes to the garbage dumps. Where was the surplus now? Suddenly the authorities realized their mistake and decided that the next crop would be left with the farmers in their cool storage pits and root cellars.

Potatoes were scarce, but there were still plenty for seed. The farmers had seen to that, and they planted every available field. The spring of 1916 was good. Young plants were luxuriant. The heavy rains made the potatoes grow. Then "the terrible plant destroyer" struck again. The rotting tubers in garbage heaps supplied the first clouds of spores, and the potato plants sickened in the fields.

What was to be done? Spray the fields with Bordeaux mixture? All the copper that Germany had must be used for shell casings and electric wire. There was certainly none to spare to make copper sulphate for potato spray.

Potatoes rotted in the fields. The 1916 harvest was as meagre as the one in 1915 had been plentiful. Soon there was such a scarcity of potatoes that people stood in long queues to obtain a few pounds. All the grain and most of the potatoes were commandeered for the army. The people behind the lines had to eat turnips or what food they could find.

By autumn the city people were hungry; at the onset of winter they were starving; by late winter hundreds of thousands of civilians were dying. Seven hundred thousand German people—the old, the weak, the children—starved to death during the winter of 1916–17!

The resistance of the Russian army had all but ended in 1916, and Germany's Eastern campaign of 1917 was a mop-up affair. The German generals knew they could now turn the combined might of all the German armies against the foes on the Western Front. But many of the rank and file German soldiers had lost the will for that last great effort. Their families were hungry, starving, and dying. "Why fight?" they asked. "For what?"

This weakening of their armies' morale may have been one of the reasons why the High Command was never able to launch a successful campaign in the West. In fact, they were forced to order their armies to retreat to a holding position on the Hindenburg Line. When British and French forces were joined by the Americans in 1917, a great new strength was brought to bear on the German front. But a saboteur, *Phytophthora infestans*, had already struck a blow against the German Empire as decisive as any campaign planned by the Allied generals. The military might of Germany began to weaken rapidly, and collapsed in November, 1918.

Although no major disaster can be blamed on this fungus enemy of mankind since 1916, late blight still causes appreciable losses of the crop that supplies one-fifth of humanity's food. The 1928 losses caused by *Phytophthora infestans* in the eastern United States ran into scores of millions of bushels. Better fungicides to be used in sprays are now available, but still as many as fifteen sprayings must be applied in some localities, and not all farmers are careful or industrious enough to give their plants adequate chemical protection.

The countries of the world maintain plant pathology centres. The universities of the world graduate thousands of plant pathologists yearly constituting a mighty force to combat the "terrible plant destroyer". But probably the greatest achievement in the struggle has been the fulfilment—after a hundred years of selection and cross-breeding—of Dr. Lindley's dream, blight-resistant potatoes. Geneticists, human experts in creation, have produced scores of potato varieties that show marked resistance to the late blight fungus, but they can never relax their vigilance. The fungus keeps fighting back.

5 Downy, Powdery, Deadly

MILDEW ON THE GRAPE

For a long time in the Medoc, that thumb of land that lies between the Gironde River and the Bay of Biscay in southern France, the habit of little boys—hungry ones or "scroungers"—had been to snatch at and carry away any grapes that were within easy reach of the roadways alongside the vineyards. The vignerons had become furious at the pilfering of these "grappleurs", and many resorted to spattering the broad green leaves and the ripening grapes with a lime and water slurry to resemble bird droppings in the hope of giving their grapes some protection from the light-fingered passers-by. Others, more than a little vindictive, added some bluestone, a substance well-known to be poisonous, to the limewater mixture. This blue-white, sickly-looking concoction would stick to the grapes and foliage even through the heavy rainstorms that often soaked the vineyards.

The summer of 1882 was particularly wet and mildew rotted the grapes, threatening to destroy the very vines themselves. Late that season, when the extent of damage to the vineyards around Bordeaux became plain, Dr. Pierre Marie Alexis Millardet, professor of botany, and former student of De Bary with doctorates in medicine and in science, was inspecting the devastated vineyards at St. Julien. He noticed that the few plants near the roadway were healthy, and heavy with well-ripened grapes. Those farther back in the vineyard were defoliated, and whatever grapes they bore were shrivelled, rotten, or unripened. On questioning the manager of the vineyard, Millardet learned the composition of the unusual concoction that remained splattered on the sound leaves and fruit.

During the next two years, Dr. Millardet experimented with mixtures of lime, iron, and copper salts, but found that the original combination was best. He then worked out the most effective proportions and published his findings in 1885, naming the new spray "Bordeaux mixture".

This Bordeaux mixture was soon certified by the agricultural scientists as the best all-round fungicide so far developed, and it gave a great stimulus to the new science of plant pathology. Its discovery was almost as amazing as the finding of the New World had been four hundred years earlier. Interest in the mixture was so great that it led to the establishment of many agricultural institutions throughout the civilized world. Experimenters learned that all, or almost all, of the major plant disease fungi were killed by the new spray. The powers of this new fungicide proved to be as useful and curative in the field of plant pathology as those of penicillin have been in the field of animal pathology. Learning the right recipe, the more progressive vignerons began to use Bordeaux mixture immediately, and within ten years its use in European vineyards was general.

Yet this remarkable fungicide was just a simple recipe composed of three cheap, common substances. The first was water, which could be drawn from any well or bailed from any pond. The second was bluestone—copper sulphate, or to be more exact, cupric sulphate—and it was almost as cheap as sugar or salt. The third component, slaked lime, could be prepared by anyone who had limestone and some wood to burn and who knew how to make and operate a lime kiln. The original Bordeaux mixture was a blending of these three substances in the proportions of about one pound of copper sulphate, two pounds of lime, and two gallons of water. Later investigations showed the mixture tended to injure the young and tender shoots because the proportion of copper was too high. Subsequently, a mixture of four pounds of copper sulphate, four pounds of lime, and fifty gallons of water was found to be effective without injuring the foliage of the sick plants.

Bordeaux mixture was found by chance. However, if credit is to go to anyone, that person should be Professor Millardet. Had it not been for his keen observation and careful experiments, this simple fungicide might have been used only against mischievous young boys who, compared to the fungi, are spoilers on a very small scale.

How long
'Fore mankind's birth

Did Allah give the gift
Of grapes to Earth?

How did
By plan Divine
Frail man contrive to make
The nectar—Wine?

How oft
The wings of Night
A cup of Wine hath clothed
In shining Light?

The grape is an ancient plant. Leaves, seeds, and stems of the vine are found as fossils in sedimentary rocks from Alaska to China. Because these fossils have been found in greater numbers in the lands around the Caspian Sea, it seems certain that the origin of the grape was somewhere in the fertile valleys of the Caucasus. From here the vine spread westward through Asia Minor into Thrace and eastward into Turkestan. The main species, *Vitis vinifera*, still grows wild and luxuriant in the forests around the Caspian.

In prehistoric times grapes formed an important item of food, eaten raw in season or dried for winter use. And ever since then this fruit has been prized by man, for many reasons. The sweet and succulent berries, charged with bouquets and flavours, are carefully cultivated on every continent of the world. There are about fifty species of grape, but the one that is most useful is *Vitis vinifera*. Over 90 per cent of the annual harvest of sixty million tons of grapes come from varieties of this vine. Twenty-five million acres of the earth's surface are planted with this one crop alone. By critical selection, aided by fortunate natural mutation, man has developed from this parent species five thousand varieties. These bear grapes that, when ripe, range in colour from green through red and purple to glossy black. Some of the varieties are used as table grapes, some are air dried into currants and raisins, and other varieties yield millions of gallons of fruit juice. But the bulk of them are pressed, the resulting musts or grape juices being fermented into wines.

There is a legend that may explain the origin of wine.

Long ago, according to Persian mythology, a great king, Jamshid, ruled the land from his capital, Persepolis. This wise and just ruler lived in power and splendour in marble palaces, surrounded by his wives, concubines, handmaidens, and slaves. Jamshid loved all the good things of his world: his wives, jewels, silken garments, rich foods, and above all, the wild grapes from his Caspian forests. He had his slaves gather these grapes and store them in huge earthen jars in the cellars of the palace so that he could eat them every day of the year.

In his palace, serving him diligently and lovingly, was a lowly maid called Almah, which means "the wise one". Her admiration for her king grew and ripened, and she yearned for him to see her not as a servant, but as a woman. Almah always adorned herself before she came into his presence; but she was a plain girl, and Jamshid did not choose her as a concubine.

Almah, the wise one, saw that there was no bond between them, and she thought of what she might do to create one. So she went down into the cellars of the palace every day and ate of the grapes, as her master, Jamshid, did. One day, when she reached into a jar, she found that the grapes had been crushed. On licking the red juice from her fingers, she spat it out of her mouth for it had a bad taste. And she hid the jar, for she thought the bad tasting juice might poison her master.

Some time later, Almah, heartened by some gesture of the king and made bold by her love for him, told Jamshid that she, too, had eaten of the grapes and had found them good. Unfortunately for her, the king became angry at her for eating his grapes and had his handmaiden punished.

In the days that followed, Almah did her work with heavy heart, so despondent that she thought of suicide. She remembered the grape jar full of its vile poison and went down to the cellar where she had hidden it. Drinking deeply of the supposed poison, Almah felt the darkness and despair leave her mind, and instead of dying, she sang and danced among the jars.

When Jamshid found her singing in the palace cellar, Almah took him to the jar and he, too, drank of the delightful poison. Then the bond that she had so desired came between them and Jamshid took her for his favourite concubine.

The scribes of Israel place the first wine maker further back in history, just after the Flood. The Ark bearing its precious cargo had grounded on the slopes of Ararat, and when the swollen waters receded,

"Noah began to be an husbandman,
and he planted a vineyard:
And he drank of the wine and was drunken."*

Wine is mentioned in the histories of all the great civilizations of the Near East as far back as 4,000 years ago. The culture of the grape spread westward to the shores of the Mediterranean. Later, Greek and Phoenician traders introduced viniculture to their colonies as far west as Italy and Spain. It was in 500 B.C. that the grape first came to France.

When the Romans came to dominate the Mediterranean, they brought to the conquered peoples Roman law and order, good roads, and stable government. The provinces found that the Senate, and later the emperors, had a pre-arranged economic plan for them. Egypt, Sicily, and North Africa were to uproot their vines and grow cereals to fill the granaries of Rome. Gaul and Britain would supply chiefly wool, tin, and lead. Spain and Italy would furnish the wines for the emperor's table. This plan lasted as long as the *Pax Romana*, two hundred years.

Wines were shipped from Spain in amphorae, large earthenware vessels each holding several gallons. Roman thirst seems to have been almost as great as Roman might, for there is a mound near Rome in which has been found the shards of an estimated forty million amphorae.

Italy and Spain might have continued to be the two vineyards of the empire had it not been for the barbarians of the northern and eastern marches. The Franks, Goths, Vandals, and the German peoples did not always submit to Roman authority, and legion after legion were sent northward and eastward to quell the frequent revolts. For a time the wine to supply these legions was brought by oxcart from Rome or from the southern coast of Gaul. Later it was found easier to bring it from Hungarian vineyards, up the Danube on barges.

A few decades after the birth of Christ, the cultivation of grapes began in the sheltered valleys of the Rhine and its tributaries and on the long slopes of the Burgundian hills. Wine caravans and barges were no longer needed, because the Romans had founded, in northern Gaul and Burgundy, new vineyards that were destined to become the most famous of all.

After the invasions of the barbarians and the inroads of the Norsemen, viniculture and wine-making declined. Not until the eleventh century, when the great trade fairs were organized in the northern cities, did wine, along with wool and salt, become a major item of trade and commerce. At this time a long series of fortunate military adventures and judicious marriages by the Norman dukes and the Plantagenet kings brought all of western France and its lush vineyards under English rule. In the ensuing three centuries the English acquired a more than moderate liking for the wines from their French possessions, especially those from the vineyards of the Gironde valley and Gascony. By 1450 the English were drinking three million gallons of Gascon wine per year.

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* Genesis 9:20-21.

When William of Orange came to the throne of England, heavy import taxes were put on French wines, and the English turned to Portugal and Spain for reasonably priced wine. So it was that port and sherry wines gained favour in England among people with discerning taste. The others drank ale and beer. With increased skill in distillation,* liquors like rum and gin became popular with the clientele of eighteenth-century English public houses. But the rich still kept their cellars stocked with fine sherries, ports, clarets, and burgundy wines. And for a hard liquor, nothing could compare with the superb cognacs and other fine brandies distilled from the wines of the Charente.

From 1500 to 1800, European adventurers and colonists carried the grape from the Eurasian countries to the other continents. Because grapes do not grow well in semi-tropical or tropical climates, European colonists were able to establish the vine only within two bands around the globe, one north of the equator and the other south, where the mean temperature ranged from 50 to 68 degrees Fahrenheit.

The grapes taken to Australia and South Africa and South America did well because of minimal damage from diseases and pests. When the colonists first came to settle along the eastern coasts of the United States they found a land full of good things. Their wives used these good things for the first Thanksgiving banquets—the sweet Indian corn, the new melons and the squash, the succulent flesh of the wild turkey. And they had big bowls of purple fox grapes, *Vitis labrusca*, and riverbank grapes, *V. vulpina*. For those who went to the south, the muscadine grapes, *V. rotundifolia* delighted their taste buds. The eastern American grapes differ from the wine grapes of Europe in having a "slip-skin", a juicy layer between the pulp and the skin, so that if the American grape is squeezed gently the skin splits and the pulp pops out. Of course, the settlers made wine from these grapes, but generally the results were not good. Sugar had to be added, and the wine, the connoisseurs said, had a very foxy or musky taste. Since it was not marketable, the hybridizers attempted to create a new plant having the hardiness of the American species and the wine-making qualities of the *V. vinifera*. The efforts to create a better American grape were successful and the Delaware, Catawba, and Concord varieties have been and are used to make wines that are quite enjoyable after one becomes accustomed to them. When the European grapes were tried in California in 1850, many of the varieties found the soil and climate suitable and the new vineyards prospered. Now the California vintages are respected as being good and sound by the wine merchants of the world.

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* The first brandy was distilled about A.D. 1300 by Arnaldus de Villa Nova, a professor of medicine at the University of Montpellier. When he tested his distillate he thought he had found the grand elixir, and he called those first spirits "the water of life". But Arnaldus got his knowledge from reading of the experiments of Jabir ibn Hayyan, an Arab scholar, who had invented the first still about A.D. 800.

Today the area devoted to viniculture is increasing rapidly, especially in Russia, the United States, and South America. The yearly world production of wine now exceeds six thousand million gallons.

"Bad things always come in threes", is a saying that the elders often repeat. Unfortunately, for the grape growers of Europe, that saying came true during the last forty years of the nineteenth century. The three plagues that ravaged the vineyards threatened to put an end to viniculture. Each plague came quietly and mysteriously.

The first of these plagues, a disease of the wine grapes, came under the observation of a remarkable English gardener, Mr. Tucker, a man without formal education in science. He was the first person in Europe to notice the new sickness.

One sunny morning in 1845, in a greenhouse at Margate, Kent, Mr. Tucker stopped beside the new shoots of his master's grapes. The young leaves were greyed by a white, mealy powder that rubbed off on his fingers. He frowned as he examined the sick plants. He had never seen the like of those limp and wilted leaves before . . . except . . . except . . . His forehead smoothed as he remembered. Once, long ago, he had seen sick peach trees, their leaves covered with the same kind of white dust. The disease of peaches was known as powdery mildew.

But Mr. Tucker was a careful and a thorough man. He talked to the other gardeners and looked at the peach trees under their care until he found one covered with powdery mildew. When he compared a mildewed peach leaf with a leaf from the sick grapes, his confidence grew; examining both leaves with a borrowed microscope, he was sure he was right. The whole surface of each leaf was felted with a tangle of tiny silvery threads. Standing from these fungal threads or hyphae were hundreds of stubby structures, each thrusting a row of white, glistening spores into the air.

Mr. Tucker's grapes were sick with a powdery mildew. A chemical that could control the mildew on peaches, Mr. Tucker reasoned, might be useful against the mildew on the grapevines. So he compounded quantities of powdered lime and sulphur, not a copper salt as in Bordeaux mixture. He spread his mixture on the tender young leaves of the grapes and waited for results. That autumn the vines under Mr. Tucker's care bore plump and sweet bunches of grapes while the other vines of Margate were devastated by disease.

Mr. Tucker finished his work on the powdery mildew of the grape by announcing his findings in a letter to the *Gardener's Journal.* Even so, this obscure man's unique contribution to plant pathology might have been overlooked or easily forgotten had not the Reverend M. J. Berkeley honoured the gardener by naming the powdery mildew pathogen of the grape, *Oidium tuckeri.* (The scientific name was later changed to *Uncinula necator.*)

The origin of this fungus disease is not definitely determined, but it is known that centuries ago the disease existed on the North American continent and destroyed the most susceptible of the wild American vines. The descendants of the surviving plants developed an immunity to the disease and, in the middle of the nineteenth century, mildew was little more than a nuisance to the grape species of America. The powdery mildew fungus came to Europe probably carried on some American vines imported for study or hybridizing experiments. It threatened the vineyards of that continent with total destruction.

In 1845 anyone could bring, without restrictions, a new plant or animal into European countries. Three decades were to pass before governments attempted to impose inspection and quarantine regulations on exotic botanical specimens brought in from other continents. The flora, domesticated and wild, of a whole continent were thus exposed to any virulent parasite that was carelessly brought in through any port of Europe.

In 1848 the first case of the disease was seen on vines near Versailles. Within five years it had reached every vineyard in Europe, North Africa, and the islands of the Mediterranean. The vines were dying even in Madeira, that golden isle five hundred miles west of Morocco. Every tender shoot, every leaf of the Rieslings, Pinots, Sauvignons, and most of the other varieties of the wine grape were infected by the Oidium. Each mildewed leaf spewed one hundred million spores into the air, and even the gentlest breeze spread these spores so that every grape leaf was touched by the deadly inoculum. Every animal, insect, bird, and person became a potential vector of the Oidium of the grape.

The matted mycelium, or body of the fungus, pushed myriads of thumblike haustoria down into the epidermal cells until the leaves withered and died. The grapes shrivelled and became infused with a grey or brown rot.

But had not Mr. Tucker found the specific control mixture of lime and sulphur on almost the same day that he discovered the disease? Had he not demonstrated the effectiveness of this mixture against powdery mildew? Certainly he had. But it is one thing to control an airborne disease inside a greenhouse; it is quite another to destroy the fungus on a whole continent.

At that time there were at least fifteen million acres in Europe where the vines stretched in endless rows. To be effective, the mixture of lime and sulphur had to be applied to each new shoot and leaf three times during the growing season. If the twenty million miles of grape-vines had been patrolled carefully by the vignerons with their sulphur-dusting bellows or syringes, the disease could have been contained. But the viniculturists, at that time, were often too careless or ignorant to apply the remedy correctly.

All during the 1850's the Oidium of the grape ravaged the vineyards of Europe. The resulting havoc forced the winegrowers to accept the laborious task of tri-seasonal sulphuring as the only alternative to ruin. So for the past century the powdery mildew has been kept in reasonable check. Only in bad seasons, wet ones, does this first plague cause serious losses. However, the vintages are no longer at the complete mercy of that first great plague of the grapes.

The second plague of the vines, and it was far worse than the first, came to Europe directly as a consequence of the first. In their years of desperation, the 1850's, many viniculturists looked for another method of control to replace the troublesome sulpher spraying. They heard that native American grapes were largely immune to the Oidium. They knew well that neither the Concord, Northern Fox, nor the muscadine grapes of the United States would make quality wine, but perhaps by crossbreeding an acceptable hybrid could be developed. A hybrid vine, producing the quality of grape necessary for the exquisite bouquet and flavour of a claret or a hock and having the tough resistance to mildew of a Concord, would save the wine industry of Europe. That was what not only the grape growers but also all of the people of France wanted. The grape was vital to the economy of the country.

Thousands of foreign grapevines were imported for hybridizing experiments, and with them came a new and elusive plague to pillage the European vineyards. The new disease was noticed in the early 1860's, and studies were instituted at once to track down and identify the pathogen. The disease was called *etise* of the vines, but later became known as Phylloxera or "dry leaf" disease.

The symptoms of Phylloxera were always the same: a yellowing or reddening of the leaves in spring or early summer and a falling of the withered leaves in July or August. There was a paltry crop of unripe fruit in the autumn, and the whole vine died the next year. The disease moved slowly and relentlessly from row to row through the vineyards, leaving ruin in its wake.

M. J. Plachon, a French plant pathologist, reasoned that since the disease spread slowly, and in all directions from a centre of infection, the organism or whatever was causing this new disease must be advancing through the soil. He concluded that the new sickness must be attacking the roots of the vines. A close examination soon revealed that the trouble was not a fungus nor a bacterium—a microscope vegetable organism—but a tiny, yellow plant louse hardly larger than a grain of sand.

These devastating little monsters, wingless females, plunged their snouts into the rich sap-bearing tissues of the grape roots. They lay enclosed in a gall, formed around them by root tissues, and gorged themselves. Then these imprisoned females would lay about twenty-five unfertilized eggs per day that would hatch and become in turn fertile females. Daily, swarms of these newly hatched wingless aphids, or plant lice, crept outwards and onwards through the soil until each found a rootlet of her own to feast on.

Pasteur claimed that the new pest had originated in America. And sure enough, when Plachon consulted with Charles Riley, the official entomologist of the State of Missouri, he learned that the Phylloxera aphid seemed to have been a natural pest of the American grapes. This association had resulted in a natural balance between the louse and the grape which did not seriously harm the plant. Moreover, the aphid was mainly a leaf parasite on the American varieties, leaving the more vital roots largely unharmed.

In its natural habitat the Phylloxera aphid, or grape louse, went through five different forms. One form sucked juices from the leaf and laid eggs. One-half of the offspring were like the parent aphid, while the other half were slimmer in form and were root dwellers. The root form laid eggs that hatched into winged insects, and the eggs of this winged form hatched into male and female lice. When these mated, the eggs produced were able to remain in the soil through the winter and hatch the next spring into the final form. This whole cycle was repeated yearly in America.

However, in their new home, the continent of Europe, these aphids were rarely able to complete their yearly cycle of five forms because of some subtle difference in the environment or the character of their new host, the wine grape. Unfortunately, too, the form that was most successful in Europe was the root type. The other kinds of Phylloxera were rarely or never found.

After much thorough study it was found that only after the fourth year of infestation did the grapevine show the characteristic symptoms of the disease. By that time the vine was doomed, and nothing more constructive could be done than to uproot it. All chemical treatments proved ineffective.

And there were many proposed remedies. Human urine, carbon disulphide, arsenic compounds, tar, and numerous other chemicals were utterly useless or of limited value. In some low-lying localities, flooding the vineyard helped by drowning the aphids, but the vines were sometimes drowned, too. High voltage electricity was tried, but the pestiferous lice were too tough to be electrocuted, or the current was dissipated before reaching them. Finally someone thought of the obvious. Why not remake the grapevine by grafting a wine grape scion to a resistant American rootstock? The deed saved the wine grape from extinction. However, the remaking of the vines of the wine grape had several drawbacks. First, it meant the labour of uprooting the vines in millions of acres of vineyards. Also, the costly process of grafting was a slow one to complete. New skills had to be acknowledged as necessary and then learned. Lastly, some of the finicky connoisseurs claimed and still claim that the new Burgundies, clarets, hocks, and sherries lack the fine qualities of the old wines.

Luckily, the march of the aphids through the soil was slow enough to allow the viniculturists time to prepare the grafted vines for replanting. Phylloxera came to France in 1865 and spread slowly through France and into Spain. The infestation of Spanish vineyards was not complete till 1918. Now, although the Phylloxera aphids are still in every vineyard of Europe, the vigilance of the vignerons assures the safety of the wine industry from this ever-present danger.

The third plague came from North America, too. Its pathogen entered Europe on one of the thousands of American grapevines of the many native species imported for grafting.

As late as 1875 the downy mildew of grapes was thought to be confined solely to the United States. It appeared in France in 1878, and in five years had spread to practically every vineyard in Europe. This rapid spread of the new mildew was aided by the excessively wet summer weather which prevailed in Western Europe during the seventies and early eighties. By this time, however, the new blight did not strike a people unused to the ways of the fungi. There were plenty of determined, educated men to observe and experiment. There was little or no foolish speculation about the cause of the new disease.

But no one could find a real cure or control.

When a grape leaf is attacked by the downy mildew fungus *Plasmopara viticola*, irregular small spots, first yellow and then brown, appear on its upper surface. If the leaf is turned over, a white-downy growth is visible. When sections of the leaf are examined under a microscope, the hyphae of the fungus can be seen to have pushed their way through the tissue between the cells. When moisture and temperature are right, the fungus forces several aerial hyphae out of each stoma in the undersurface of the leaf. These become branched, and branched again, and bear a spore on each tiny final branchlet, so that the whole spore mass resembles a microscopic bunch of grapes. These are spread by high winds or heavy rains.

When the weather is wet and cool, as it was that summer of 1882 when the disease struck France in full force, each of the aerial spores goes through an internal change, producing a swarm of tiny zoospores. If the surface of the leaf is moist, the zoospores swim about for a while. When the zoospores stop moving, they germinate by sending out a long hypha, or thread. When this infection thread reaches an open stoma, one of the minute natural openings on the lower epidermis, the fungus will quickly establish a new colony.

Towards autumn this fungus often develops male and female sex cells, gametes. These, in turn, unite to form tough, thick-walled oospores, which are spores formed by sexual methods. The oospores, because of their protective covering, are able to remain alive throughout the winter. In the spring they germinate to form the new conidiospores, the aerial spores, which are windblown or rain-splashed to the new tender, spring leaves of the grape, and the life cycle of the fungus begins again.

The fungus attack on the leaves weakens the plant and the grapes rot. In an abnormally wet season the losses to the viniculturists are enormous. And those losses were suffered for five vintage seasons before a remedy was found—Bordeaux mixture.

The effects of the three grape plagues on the wine-producing nations of Western Europe were chiefly economic, but land use was not greatly affected, for the majority of the vignerons stubbornly refused to change their way of life. They had learned grape-growing from their fathers, and their fathers from their fathers, and they knew little about any other form of agriculture. In very few instances did they change to grazing or grain-growing. Perhaps the chalky and gravelly vineyard soil was not suited for other crops. But most likely it was the tenacity of the vignerons themselves that kept the land from being put to other use when the three diseases—Oidium, Phylloxera, and downy mildew—destroyed the vines of Europe.

The annual production of wine in France, before the onslaught of Oidium, was averaging about a thousand million gallons. By 1854, at the height of the powdery mildew blight, output had dropped by 80 per cent to slightly over two hundred million gallons. Moreover, the quality of this wine from the mildewed grapes was generally poor. Although the better vintages in storage could be depleted to satisfy the demands of the export trade, the income of the viniculturists dropped alarmingly. To offset the drop in quantity, shippers raised the price of wine, and so the less scrupulous, tempted by the resulting demand for cheaper wines, scoured the countryside. The quality of the wines shipped did no credit to the vignerons. And what was far worse, the foreign consumers—the potential regular purchasers—got their first face-twisting taste of bad wine.

The ports and sherries from Portugal and Spain suffered the same deterioration. The exquisite madeiras almost disappeared from the market, for Oidium struck the island vineyards such a devastating blow that many inhabitants tore up the sick vines and planted their land with melons and sugar cane. But tons of lime sulphur and plenty of hard work saved the wine industry of Europe. In France, by the late 1860's, the yearly production had climbed to more than 1,300 million gallons.

At this time, too, Prime Minister Gladstone stimulated the lagging wine imports to Great Britain. In order to correct the sottish drunkenness of the gin era when one could "get drunk for tuppence and dead drunk for sixpence", Gladstone lowered the import duties on wines to less than half their former rate. Moreover, his government granted grocers, drapers, and other shopkeepers the right to sell wines. As a result of the increased number of wine sellers, the consumption of imported sherries, ports, and other wines rose quickly. In the fifteenth century the English had been drinking over a gallon of wine per person yearly. Now in the 1860's and early seventies, many cellars were again filled with fine wines. Moreover, brandy and soda became the drink in the clubs and in the drawing rooms of the well-to-do.

Unfortunately for the continental vintners, it was at this same time that the Phylloxera louse began its slow, killing creep through the European vineyards. Almost certainly the French vignerons could have established a control before the louse became widespread if the energies of France had not been drained away to fight a more pressing and dangerous enemy.

Emperor Napoleon III, eager to maintain the political and military prestige of France and to keep the German state of Prussia from dominating Europe, tried to thwart Prussia's statesman, Bismarck, in his drive to unify the German states. The political struggle led finally to the Franco-Prussian War, begun in July, 1870, and ended ten months later with the complete defeat of France. The French had to cede Alsace and part of Lorraine to Germany. In addition, France had to pay a staggering war indemnity of five thousand million francs and submit to a German army of occupation for the next three years.

The French lost their vineyards in Alsace and Lorraine to the armies of the Germans, and those vineyards in all the rest of France to the hordes of the Phylloxera. This disaster cost the French nation one hundred thousand million francs for immediate replanting and countless millions more in the loss of their future wine and brandy markets throughout the world.

What had happened to the French viniculturists in their struggle with Phylloxera was repeated in Portugal, Spain, Madeira, Italy, and the other countries of Europe over the next two decades. The losses to those other countries were comparable to those of France. Therefore, by extrapolation, an estimate of the accountable loss to the winegrowers of the world, who normally produced about four thousand million gallons of wine annually before Phylloxera, would be about one hundred thousand million dollars.

Hardly had the skilled winegrowers, with almost superhuman effort, solved the problem of how to keep the grape louse at bay, when the Plasmopara or downy mildew fungus began its feast on the lush, new vine graftings.

No one has ever estimated the monetary loss accountable to downy mildew, but a reasonable guess would place it at about fifty thousand million dollars, or about one-half that caused by the Phylloxera louse. Because there was an overlapping of the three diseases, the loss attributable to the last one is most difficult to determine, but in the 1880's and 1890's, the yearly output of the combined wine producers of Europe dropped below that of the 1840's, sometimes to little more than half. However, the toll taken by downy mildew superimposed upon the losses due to Oidium and Phylloxera, whose pathogens are still present in the vineyards of the world in this century, brought the vignerons once again face to face with ruin.

Had these three plagues been visited upon the winegrowers in one man's working lifetime, the effects would have been overwhelming. Fortunately, these diseases of the grape were spread out in time and ran their devastating courses through three generations.

Now to a more spirited result of these diseases of the grape.

Northwest of France lies a group of islands in which a conglomerate population, held together by common interests and isolation, has prospered. The English, ambitious and vigorous, have dominated the Celtic remnants of the ancient civilization of these islands and, through the centuries since the Romans, have forced the Irish, Welsh, and Scots into a grudging "cooperation". Now they are at peace and, except for bombing a few post offices, booing one another's soccer teams, and bloodying noses in public house brawls, they all live in harmony.

But it was not always so. Many differences, such as the Gaelic language, the Roman Catholic faith, the fierce allegiance to the Stuart kings, and the preference for an unholy drink, long kept the English from appreciating the fine qualities of their Celtic subjects and neighbours. In fact, it is said that the English, as late as two hundred years ago, regarded the Highland Scots as sheep-stealers who, in their spare time, skulked about the dank and gloomy glens of the north concocting new recipes and refinements for distilling a foul-tasting firewater called whiskey, or in Gaelic *usquebaugh*—the water of life.

At the same time the Irish were labelled as bog-trotting rebels who, between bouts of brawling and fantasy, made an equally evil potion which they, too, called "the water of life". Neither Irish whiskey, nor Scotch "whisky", was considered fit for Englishman or beast, being thought of as home brews of the crudest types. The Irish and the Scots smiled inwardly, knowing that if by chance some ancient Greek had had the opportunity to down these drinks, he would have been sure that he truly was a god.

Out of pure meanness, the Scots said, the English passed a law in 1787 imposing an excise duty on spirits according to the capacity of the still, and limited the sale of whiskey to the Highlands. An army of government inspectors—gaugers—descended on the restive Highlanders and "troubles" began again.

The outbreak was called the Smugglers War. In truth, it turned out to be a battle of wits. After many broken heads and thirty-five years of bad feelings, the Sassenach, the Gaelic word for Saxons, knuckled under, allowing any Highlander to run a still after payment of a licence fee. The first licensed distillery of Highland whiskey was built in 1824, but illicit distilling went on for another fifty years.

Practically every drop of whiskey made was consumed in the land of its origin, and a lot was made. In 1840 the fifteen million English drank eight million gallons of brandy, gin, and rum—one-half gallon per mouth. The Irish, notorious quaffers, downed five million gallons of whiskey at the rate of two-thirds of a gallon per person. Down the gullets of two and a half million Scots poured six million gallons of what they claimed to be pure nectar. The "braw" Scots consumed two and a third gallons per person.

Take the finest malting barley. Sprout it and heat it over a low, smoky peat fire. Mix in the water of a Highland stream and add yeast. After fermentation, place the beerlike brew in a copper pot still and heat lovingly. The clear and pungent nectar dripping from the copper coil of the still will become, after colouring with burnt caramel, the finest whiskey, one that glows with golden light long after the sun has dropped to rest behind the glens and hills of bonnie Scotland. That is the pot still of the Highlands, the whiskey with a unique and distinctive taste that the Sassenach stomachs could not abide.

In 1830 an Irishman, Coffey, invented a patent still—a continuous still—and whiskey making was speeded up. Patent-still whiskey could be made twenty or thirty times faster than pot-still whiskey, but it had little "character". Moreover, the patent still could be used to make the cheaper grain whiskey of the Lowlands, where unmalted grain, usually corn, but sometimes rye and oats, mingled with malted barley. These grain spirits from the patent stills were carefully blended with chosen malt whiskey from the Highland pot stills, and this blend was labelled Scotch whiskey. Each distillery now has its own carefully guarded secret recipe and never varies it as long as it fills the needs of enough satisfied customers.

The production of Scotch whiskey in 1840 had been about nine million gallons, a rate that held steady through the fifties and sixties. During the same period the consumption of brandy in England had remained at about one and a half million gallons per year. In 1870 the Scots had made fourteen million gallons of whiskey, presumably drinking more than half of it themselves. The seventies had been the decade of lowered duties on wines and high consumption of brandy in England. Then Phylloxera and downy mildew had come to the vineyards, almost together, in the same decade, stemming the flow of wine and brandy. The canny and energetic Scotch distillers, sending their master salesmen south to London and with their new and somewhat more palatable blended Scotch whiskies, had rescued the thirsty English.

In 1880 the Scots made eighteen million gallons of their golden liquor. By 1890 the output was twenty million gallons per year, and in 1900 the rout of brandy was complete. That year the Scots made thirty-one million gallons of what the once stubborn English now realized was the world's finest liquor. The French and other European brandy makers, with the three dread grape plagues now under control, were anxious to reconvince the British of the superlative quality of their cognacs and other brandies, but the time was past and the effort vain. The English had come to prefer the whiskey they had once despised.

Scotch, replacing brandy and soda, remained the favourite British drink. The Americans, too, gradually became fond of their own corn whiskey, and so the European vintners and distillers lost a great part of the American market. Now, a century later, interest in fine wines is increasing, but the lists of fine imported wines and brandies are still very short.

6 An Economy in Ruins

COFFEE RUST

Some diseases affecting the crops of mankind exhibit symptoms that are very apparent; others have symptoms that are scarcely noticeable. Moreover, the severity of the losses from disease varies widely according to the susceptibility of a particular crop and the vagaries of climate. Little wonder, then, that some peoples of the world came to understand the importance of the science of plant pathology sooner than others, and that some nations have produced more plant pathologists than others.

In the early nineteenth century, several Frenchmen made startling and fundamental discoveries in the investigation and control of fungi. During the middle of the century, German scientists also made outstanding contributions in this field. Great men like Anton De Bary, who worked on the grain rusts and smuts as well as the late blight of potatoes, and Dr. Julius Kuhn, who was honoured by the title of Father of Modern Phytopathology, led the way for scores of their students.

But by the turn of the century, leadership in this field of science moved to America. American plant pathologists, also called phytopathologists, such as Thomas Burrill, professor of botany at the University of Illinois, who did outstanding pioneer work in bacterial diseases, were superbly trained and used the finest scientific equipment. They made important contributions to the world's knowledge of plant diseases.

About the time that Russian shot and shell were making a hell for the English soldiers in the Crimea, Henry Marshall Ward, England's famous plant pathologist, was born. Even as a boy he wanted to be a science teacher and later, in 1876, he got a job as science demonstrator at the Science and Art Department at South Kensington. That same year he won a scholarship to Christ's College, Cambridge; three years later he was granted a first-class degree in botany. During his years at Cambridge, Ward became fascinated by plant diseases, and after graduating went to Germany to study under the great De Bary. He had completed a year of study under that brilliant phytopathologist when he received an urgent request from his homeland.

The authorities at Kew Botanical Gardens asked him to go out to Ceylon and try to cure the coffee-leaf disease. The planters on that island were desperate.

The work of this 25-year-old Englishman in Ceylon will always stand as one of the masterpieces of scientific sleuthing. He followed the experimental method and made his observations carefully. Within two years, Ward was able to trace the entire life history of the fungus parasite that was killing all the coffee plants of that island. He presented his report, "The Colombo Sessional Paper", to the Ceylon government. But the worried planters were not in the mood to appreciate his explanation of the disease; they wanted a cure.

Since the planters had virtually stripped the native trees from land suitable for coffee growing, every gentle breeze wafted the disease inoculum across the coffee plantations. Ward knew that only an attack on the germinating spores, the most vulnerable stage of the fungus, held a promise of success. Sulphur or sulphur with lime proved ineffective, and Bordeaux mixture had not yet been discovered.

In the eyes of the coffee planters, Henry Marshall Ward was a failure; he could not rescue the coffee crop of Ceylon. But as a scientist he stands out as one of the greatest that England has produced.

From 1953 to 1955 coffee ranked first in value among all the agricultural exports of the world and, among all commodities, ranked second only to petroleum products. In 1960 over eight thousand million pounds of coffee were produced in four of the five land masses of the world. The coffee-growing countries lie largely between the Tropics of Cancer and Capricorn. Brazil is the largest producer, with Colombia ranking second. The countries of Central Africa, India, and Indonesia grow most of the remaining tonnage. The amount of coffee grown and processed yearly is enough to brew some five hundred thousand million cups of one of the most aromatic and satisfying drinks ever consumed by mankind.

The refreshing and stimulating effects of coffee are due to the presence of a water soluble alkaloid, caffeine, in the beans of the plant. This substance produces, without any alteration in consciousness, an apparent excitation of the mental processes, and is a drug widely used to relieve fatigue.

Caffeine, apparently a waste product of the metabolic processes, accumulates in the seed of the coffee berry and in the leaves of a few other plants, one of which is tea. It constitutes 2 per cent (dry weight) of the coffee seed or bean, as it is commonly called, and 5 per cent of the tea leaf. Both plants rid themselves of this accumulated waste by dropping the coffee berry or shedding the tea leaf.

If the effect of alkaloidal caffeine is the main reason for drinking coffee, and if tea contains at least twice as much caffeine, why then is coffee the principal choice by the people of the world of a stimulating drink? The answer is not very complicated. Tea leaves contain a high percentage of tannin—a bitter, unsavoury chemical. If more than the minimum amount of tannin is released during the brewing process, tea, instead of being a light, aromatic drink, becomes dark, heavy, and astringent. Thus, tea must not be boiled but only allowed to steep for a very short time in order to be good. But since tea brewed in this manner contains less than a third of the caffeine in a normal cup of coffee, a good cup of coffee is at least three times as stimulating as a cup of tea. The general acceptance of the "coffee break" indicates the effectiveness of this nerve stimulant, caffeine.

Some time before A.D. 1000 the Arabs brought the first coffee plants or coffee seeds across the Red Sea from Ethiopia to that area of the Arabian peninsula now known as Yemen. There, coffee was first cultivated and brewed. However, for a long time only the mullahs drank coffee, possibly to sustain them during the long and tiring religious rites of Islam.

Little is known of the use of coffee before the sixteenth century. Records of that period show that Turkish coffeehouses were doing a thriving business as early as 1554; the new drink reached Venice by 1560, and the Portuguese knew of it before 1600. But for many years coffee was a luxury beyond the purse of the common man. The supply was very limited because from the time the Arabs brought the seeds or plants from Ethiopia, they zealously guarded them, allowing no infidel visitor to leave that land with so much as one unroasted bean. But as the fame of the new exotic drink of Arabia spread through Europe, royalty, the rich lords, and the wealthy merchants vied for every roasted bean that reached the European ports. Prices rose. An ounce of coffee once sold for five pounds sterling on the London market. It was inevitable that adventurers all over Europe would scheme to smuggle viable coffee seeds from the Arabian port of Mocha. However, the faithful were vigilant, and for years the schemes came to nothing.

Unknown to the bold and scheming Europeans, someone had already made off with the prize of Araby. A lowly Muslim had come from the southern hills of India some time around A.D. 1600 to make his holy pilgrimage. He had thirsted to see the Prophet's tomb and the Holy Stone of Islam, thus winning the right to wear the green turban of a haiji. He saw the tomb of Muhammad and the great, black stone polished by the kisses of the faithful, and he was given a bowl of steaming coffee to aid him in his vigil.

Somehow, he was able to get up into the hills and gather the "seven seeds". He bound these viable, unroasted coffee seeds to his body and returned to the hills of Chikmagalur in the Western Ghats of southern India. The seedlings that came from the seven seeds flourished in the warm soil, and when the Dutch came to India as traders, they found coffee trees scattered throughout the hill country all the way from the central provinces to the southern tip.

The Dutch, anxious to develop the resources of their colonies, carried some of these plants to their newly won possession, Ceylon. In the last half of the seventeenth century the men of Holland became the planters of the eastern tropics. They planted coffee in Java and Sumatra, and it flourished there, too. Then about 1690, to top their accomplishments, the energetic Dutch planters of the East Indies wheedled some coffee trees directly from the Arabian authorities and from the tribesmen of Ethiopia. It was one of these trees that they sent back from Java to Amsterdam as a botanical curiosity for their stay-at-home countrymen to see on their visits to the greenhouses in the Physik Gardens. In 1713 a five-foot tree from the Amsterdam greenhouses was given to the king of France. That tree, tended with special care, was destined to be the ancestor of the bulk of the millions of coffee trees of the Western Hemisphere. From it came plantings that spread through the Caribbean Islands and on the mainland from Brazil to Mexico.

It was in Amsterdam that the man who scientifically renamed thousands of living plants and animals saw his first living coffee tree. Carl Linné, a biology student at Uppsala University, Sweden, became Carolus Linnaeus the greatest taxonomist the world has produced.

Even as a student, Linnaeus was critical of the complete lack of logic used by naturalists when naming plants and animals. Compounding the international muddle was the multiplicity of common names used by the people even within one country to denote one simple plant. With characteristic energy and wisdom, he laid down his binomial system of taxonomy in 1737. To help make his system acceptable to scholars, he chose the classical languages, Latin and Greek, to serve as word reservoirs in naming plants and animals.

Linnaeus was impressed by the pretty little coffee tree with its glossy, green leaves and its bright red berries in the Amsterdam greenhouse, and he set about to give it an appropriate name. He knew that just as "All Gaul was divided into three parts", so all plants could be grouped into four parts—four great divisions, or phyla. The coffee tree, a flowering plant, belonged in the fourth phylum, the Spermatophytes, or seed plants.

When he examined the shiny berries of the tree, he saw that the seeds were completely protected by the fleshy pulp of the fruit; this characteristic meant that the coffee plant belonged to the sub-group he had called Angiosperms, as distinguished from the cone-bearing plants that had naked seeds. Then when he looked at a seed of the plant, he noted two divisions or cotyledons—nurse leaves—and so he classified the plant as a member of the dicotyledon group. At this point he had to be more exact and searching in his observations. Because flower structures are the main criteria used to determine the relationship of newly found seed plants, Linnaeus procured a single flower of the coffee plant. When he saw its five-petalled trumpet shape and the position and form of its stamens and pistil, he remembered that he had seen many plants, such as gardenia and madder, with similar blossoms. This family of plants he had already called the Rubiaceae, so he concluded that coffee should also be classified as a member of that family.

So far he had followed the rules of scientific naming that he, himself, had laid down. Now he must invent a name for this new genus of plant. What better name than that which the Arabs, themselves, called it? He chose "Coffea" a latinized version of "kahwah", the name which the mullahs and dervishes had given the plant centuries before. Lest other trees very similar to it be found in the future, he searched for a specific designation, finally choosing "arabica" to connect it with the country of its origin. Had Linnaeus known that the Harari tribesmen of Ethiopia had chewed and eaten the berries of these plants for extra energy on their long journeys, he might have chosen "ethiopica" or "abbysinica" for its specific name.

According to Linnaeus, the coffee tree's genealogy is:

Phylum—Spermatophyta
Sub-phylum—Angiosperms
Class—Dicotyledons
Family—Rubiaceae
Genus—Coffea
Species—arabica

Linnaeus wrote a description of the new plant and so proclaimed to the scientific world that henceforth the official name of all coffee trees similar to the one in the Amsterdam Physik Gardens would be *Coffea arabica*. Linnaeus was correct in his classification, and also correct in his guess that there might be other caffeine-producing trees closely resembling *Coffea arabica*. About sixty species of coffee have since been discovered, the main rival of the original in strength and other desirable qualities being *Coffea canephora*. But none of the present species, natural or hybrid, were available to prevent the disaster that struck Ceylon.

In the seventeenth and eighteenth centuries, Holland's eastern empire was flourishing; the dikes were holding in the homeland; tulips were blooming in all their beauty; and the Dutch had some promising coffee plantations in Ceylon and Java. Then in 1794 the French, revolting against the aristocratic tyranny at home and piqued at the Dutch government's official attitude towards their newborn republic, sent their vigorous armies against the Netherlands. Holland was overrun and her erstwhile ally, Britain, in order to forestall Napoleon's drive for supreme power in the world and to prevent his seizure of the Dutch colonies of the East, took Ceylon in 1797. But the English, preoccupied with Bonaparte, had neither the money nor men to carry on the coffee plantings of the Dutch. The old plantations gradually disappeared, smothered by the pressure of the encroaching jungles.

The British finally rid Europe of Napoleon's armies in 1815 and, after a national breathing spell, returned to the peaceful pursuits of developing their colonies and improving their position in world trade. In 1825, Sir Edward Barnes, remembering the Dutch enterprises, planted new coffee trees near Kandy in the highlands of Ceylon, with the blessing of the British Home Office. The little trees flourished, and the government, hoping to profit by the growing coffee markets of Europe, exempted new plantations from land tax and export duty. Strangely, the import tax on coffee from Ceylon was nine pence per pound, compared with that of six pence per pound from the West Indies. But in 1835 the injustice was corrected, and the great rush for coffee land in Ceylon was on.

In 1835 only four hundred acres of Crown Land had been sold to planters, but in 1841 the figure was eight thousand. Development was slowed but not halted in 1845 by a disastrous market crash. By 1870 Ceylon exported one hundred million pounds of coffee a year. The country was booming. Almost four hundred thousand acres of choice highland were green with the lush growth of the fabulous new crop. Hundreds of thousands of Singhalese were working in the plantations, but their numbers were not enough. Many Tamils, workers from southern India, were brought over to help in cultivation and processing. Still other thousands of workers were building roads through the jungle, connecting Colombo with the coffee plantations.

Lines of bullock carts hauled the dried beans down to the sea. The planters tore their hair as they watched the slow coffee caravans. More coffee was piling up in the sheds on their plantations than was getting to the ships. There had to be a railroad. Committees met, sent petitions to the government, but the glut of coffee grew. Strangers to Ceylon crowded the hotels and speculated on land. Money poured into Ceylon like the rains of the summer monsoon. Everyone was caught in the coffee fever. The planters grew well-to-do, then wealthy, then rich beyond their wildest dreams. Huge, luxurious bungalows were rushed to completion in order to house the planters' families. Coffee from Ceylon became one of the Empire's most valuable products.

Only one man in Ceylon was against the boom. "Ceylon will be ruined," he said. "Any country that gambles its future against the quick wealth that comes from a single crop is inviting bankruptcy." No one listened to that eccentric scientist at the botanic gardens at Kandy. What did he know about business, or about coffee? Pruning roses—Yes! Coffee—No! Dr. H. H. K. Thwaites, Superintendent of the Royal Botanic Gardens, got nowhere in his quiet campaign to persuade the planters to diversify their crops.

Nevertheless, an insidious killer was skulking in Ceylon. Maybe it had been there, existing on the wild relatives of *Coffea arabica*, since the beginning of time. A few diseased leaves from an old infected Dutch planting may have been caught up in the swirling winds and blown into a coffee plantation in the dead of a misty night. By whatever means, the fungus did get into the plantations, and by the time the railway to Kandy was completed in 1875, the coffee rust was killing the bearing trees as fast as the young ones were planted. By 1886 production was down to eighteen million pounds, and in 1889 it had dwindled to five million pounds. By 1892 there was scarcely a healthy coffee tree in all Ceylon. Within fifteen years, Ceylon, leader of the coffee-producing countries of the world, was producing not one sack of beans for export. To have enough coffee for their own use, the Singhalese were forced to import.

Hemileia vastatrix, the coffee rust fungus, was first studied by Dr. Berkeley in 1873, but it was H. M. Ward who made the most exhaustive study of its life history. This rust fungus is closely related to those that attack the grains and grasses of the world. It is now thought to have originated in the same region of Africa where its host, the coffee plant, originated millions of years ago. This rust, like all its related killers, spreads itself by spores that are carried on the winds. If a living spore falls on a coffee leaf when the weather is favourable—warm and humid—it germinates and its germinating thread penetrates the leaf. Once inside the leaf, the mycelium of the fungus grows with frightening rapidity. In a few weeks the mycelium, with its multitude of haustoria, has absorbed enough of the life-giving food of the coffee leaf to produce reproductive spores. It breaks through the porelike stomata on the under epidermis of the leaf and produces pustules, or sori, each of which throws off into the air as many as one hundred thousand yellow-orange summer spores. Every coffee tree soon has thousands of these spore-bearing sori. The winds, rains, and insects, even the workers themselves, aid the fungus in spreading the millions of spores. Within two or three months every susceptible coffee tree within miles of the original infection becomes sick. When the dry season comes to the plantation, the coffee tree—an evergreen that normally sheds its leaves throughout the year, a few at a time—is so weakened that it drops all its leaves in one season. True, with the coming of the monsoon rains the diseased tree puts out a new set of leaves in an effort to survive. But the fungus strikes again and again; after a few defoliations the tree is so debilitated that secondary diseases kill it.

Like the other fungi, the coffee rust flourishes when the winds are light and warm, and mists and drizzles keep the coffee leaves moist. Since it attacks unshaded fields, wise plantation managers plant shade trees among the coffee trees. Another good practice is to plant at a high altitude, above the warm mists and drizzles. Spraying with Bordeaux mixture will help to reduce the losses from the coffee rust's attack, although no chemical spray yet discovered will kill the fungus outright. No matter what is done, if the strain or variety of coffee is susceptible to Hemileia, the trees will become so weakened that profitable coffee production cannot be sustained in an area where attacks by the fungus occur yearly.

The most satisfactory defence is to find or develop varieties of coffee that have a strong resistance to the rust. Fortunately, such plants exist; otherwise, coffee would probably disappear like the American chestnut.

A variety of *arabica* called Kent's, found near Chikmagalur, India, was quite resistant, and its beans made a good cup of coffee. But Kent's slowly lost its resistance as virulent new strains of the rust developed in the Indian plantations. The coffee breeders and agricultural researchers did not give up. They searched for and crossbred promising plants until they developed S.333. This variety of *Coffea arabica* is, so far, robust, vigorous, and rust resistant.

More and more growers in the East Indies and in the Western Hemisphere are trying a hardy African species, *C. canephora*—often called *C. robusta*. It has a high caffeine content and is very resistant to the rust. Growers hope that there are enough bearing *C. canephora* trees to satisfy the coffee drinkers of the world if ever coffee rust destroys the last of the *C. arabica* trees.

Ceylon was the foremost coffee-producing country of the world in 1870, and the coffee planters were very optimistic about the future of this profitable industry. Then the rust came.

At first the infections were scattered and the busy coffee planters paid little attention to the disease. Instead of trying to help the sick trees, the plantation owners bought more land and planted more coffee seedlings. Everyone hoped that either the rains of the wet monsoon would wash the leaves clean of the rust spots or that the hot winds of the dry monsoon would dessicate the fungus and end the menace.

The disease worsened and the coffee crops got smaller season by season. Acting under pressure from the worried planters, the government of Ceylon, in 1879, set up a special commission to study the disease. An urgent appeal was sent to London for help to save the coffee plantations.

The homeland responded. Trained workers were sent to the East on the first boat and they worked feverishly to unravel the rust's life history and find its weakness. But the vulnerable stage of the fungus remained a mystery until Henry Marshall Ward came to Ceylon.

At first Ward was appalled at the jungle and its multitudinous life. The great variety of the jungle plants and the many kinds of parasitic fungi overwhelmed him. But he forgot all that when he saw the sick coffee trees enmeshed in a living web of fungi mycelia which smothered them with a mistlike tangle of hyphae.

A lesser man would have been daunted, but Ward plunged into the jungle and into his work. He hung sticky glass slides on the coffee trees and collected samples of fungal spores, some of them being the half-smooth urediospores of the dreaded rust. He sectioned leaves and examined them through his microscope. With painstaking care, Ward unravelled the mysterious reproductive life of the coffee rust and found the tough black teliospores that were hardy enough to withstand the most severe drought. He saw these teliospores sprout their basidia, club-shaped structures, each producing four basidiospores that are able to infect young coffee leaves. He saw everything and he recorded everything.

Ward even showed the coffee plantation people how to spray their sick trees with a lime sulphur mixture. But the spraying idea came too late. The rust spores were too widespread, too numerous. Spraying, even though it checked the fungus and raised the yield of coffee, was too expensive for the nearly bankrupt planters. The sick trees bore fewer and fewer coffee beans and Ceylon was face to face with ruin. The planters' income dropped at the rate of ten million dollars annually.

There was only one thing to do. The plantation owners planted tea. In 1875 there were only one thousand acres of tea on the island, but they were prospering, and when the desperate planters of Ceylon looked at the flourishing tea plantations of Assam, they realized that this was a crop that the rust fungus would not destroy. Within five years, tea bushes of the new plantings greened the fertile hillsides as far as the eye could see—three hundred thousand acres of them.

Replanting with tea was a stupendous undertaking. Never before, nor since, has a country been forced to change its principal crop so completely in such a short time. What a remarkable group of men those planters must have been! Many of them were bankrupt from the failure of the coffee crop. The Oriental Bank had closed its doors, and the life savings of thousands had disappeared in the resulting crash.

The government-owned railway running from Colombo to Kandy, with its spur lines that had been built to serve the surrounding coffee country, was losing money steadily. It seemed that both the planters and the government faced complete bankruptcy. In worse condition were the thousands and thousands of Tamils from southern India and the native Singhalese, who had scarcely earned enough on the plantations and in the coffee mills to buy their daily rice. They were not needed now that the coffee plantations were in ruins. The resulting hardship and starvation added to the turmoil and confusion. As a result of appeals to the government in London, the Royal Navy assisted in the transportation of the thousands of Tamils back across the Gulf of Mannar to India. In one of the most spectacular forced migrations of modern times, the people did not flee the roar of cannon or the tramp of foreign regiments: they fled before an enemy that exploded in the quiet Ceylon night.

During this economic disruption, the planters somehow got the money to buy tea seedlings and transport them from northern India. Raising money was certainly not easy, for the economy of the homeland had also suffered during a depression that lasted from 1876 to 1880. Four hundred of the seventeen hundred planters gave up and pulled out of Ceylon, but the rest hung on and sweated in the tropical heat as the changeover was made.

From 2,500 to 4,500 tea bushes are needed to plant an acre. Therefore, to plant three hundred thousand acres, over a thousand million tea seedlings had to be grown or bought, carried to the fields, then heeled in. Workers had to be paid; and even though wages in Ceylon were unbelievably low—six pence per day—the cost of the thousands of field hands was an overwhelming financial burden. On top of all this, the young bushes would not come into reasonably full production for five or six years. Would there be a market then? India, Japan, and China were already supplying the tea drinkers of the world. These new plantations would produce another two hundred million pounds of tea annually, enough for an additional fifty thousand million cups. Who was going to drink all this tea? These were but some of the questions and problems for the planters to worry about. Other questions remained to be answered, too. Could quality tea be grown in Ceylon? Would some disease wipe out tea, as it had coffee?

The coffee-rust disease, having ruined the plantations in Ceylon, continued its depredations elsewhere. All over Southeast Asia the rich coffee plantations were falling before the insidious attack of the deadly rust. It was all over by the turn of the century. There was scarcely enough export coffee in all the East to fill one freighter per year. The coffee rust spores rode the monsoons and laid waste the plantations of south India. The Dutch, in their East India possessions, were forced to replant their coffee plantations, but they chose rubber instead of tea. In the space of one decade the coffee industry of a continent was destroyed.

Coffee's history in England dates back to the days of Oliver Cromwell. When Cromwell became lord protector, one of the many worries that beset him was the sottishness that prevailed in Merrie Olde England. The civil war, with its aftermath of misery and poverty, had swamped all the people except the Puritans in a sea of melancholy. Many of the gentry, merchants, and men of learning, as well as the common people, proceeded with the only cure at hand; they drowned their wits in oceans of ale, strong beer, and wine. Even Oxford, the university town, had three hundred and fifty ale houses.

The lord protector, urged by his conscience and his Puritan colleagues, desired with all his soul to wipe out the taverns with one stroke of his pen. But he dared not. He feared the populace, denied beer, that cheap and accustomed panacea for frustrations and woes, would riot. There was enough incipient royalist opposition to his dictatorship without adding to it. Abolishing the taverns would surely stir the discontent into another bloody internecine war and, once again, brother might slay brot

But in a strange and roundabout way the protector did, unknowingly, help reduce the common drunkenness of the time, by setting his hand to a proclamation that allowed the Jews to come back to England.

One of the first of the new immigrants was a man named Jacob who came to Oxford with a dream, and with a sack of coffee beans. He established a coffeehouse in 1650; it was a great success. All who came and tasted his brew learned the truth of what Bacon had written long before: "They have in Turkey a drink called coffa, made of a Berry of the same Name, as black as Soot, and of a Strong Scent which they take, beaten into Powder, in Water as Hot as they can Drink it: and sit at their Coffa-houses, which are like our Taverns. This Drink comforteth the Brain, and Heart, and helpeth Digestion."

Bacon certainly could have added, "and it resulteth not in sore Heads nor Hangovers".

The coffeehouse caught the jaded English fancy. A Turk opened the first one in London in 1652, and others were established almost as rapidly as the smiles of enjoyment came to patrons' faces when they tasted the first steaming cup of the new drink. By the end of the century there were, in London alone, more than two thousand houses where men could drink the stimulating brew.

For a century the coffeehouses were the meeting places of scholars, poets, scientists, and men of business. The roll call of their patrons includes the name of almost every great man that Britain produced from the Restoration to the fall of Napoleon. Dryden, Swift, Boyle, Wren, Newton, Goldsmith, and Gainsborough were but seven of the thousands who quaffed coffee and exchanged brilliant conversation.

It was not all sugar and cream for the coffee men, though. First, the Great Fire of 1666 wiped out scores of the houses. Then Charles II, in 1675, alarmed at the talk of sedition among the patrons, issued a proclamation revoking the licences of the owners. But the outcry was so great that after ten tempestuous days the government felt it wise to rescind the order. There has never been a shorter prohibition in recorded history!

Gradually, however, an influx of pads, pimps, cutthroats, and quacks gave the standard coffeehouse a bad name, and the patronage of honest men dropped off. When many of the coffeehouses evolved into private clubs, towards the end of the eighteenth century, the death knell had sounded. Most closed their doors; some changed to chophouses; others became public houses; and only a few struggled on for a time. The former patrons, however, did not give up their savoury, morning-noon-and-evening coffee. A pound or two of coffee beans came into the pantry each week, and the cook learned how to brew the master's favourite drink.

During the last few decades of the coffeehouses' existence, the other caffeine drink, tea, was becoming popular. About three hundred cups of tea could be brewed from each pound, as against thirty or forty from a pound of coffee. Tea's cheapness, therefore, recommended it to the frugal and allowed the poor to get a little caffeine into their bloodstreams on a chilly morning or during a long tiring afternoon. By 1850 tea was being drunk cup for cup with coffee. Moreover, it was government policy to promote Empire trade and, as India was the prime producer of tea, the owners of the fast clipper ships and the new lumbering steam freighters were encouraged to ship tea. This they did in ever-increasing volume, piling high the docks in London with leaded tea chests from Assam.

England had been getting its coffee from the British colonies in the West Indies, but the slaves who had been freed in 1833 were loath to continue working on the coffee plantations, and production fell off. Thus the new and increasing coffee production in Ceylon in the 1860's and 1870's supplied the demand. It was natural and loyal, then, for the English to take to tea drinking when *Hemileia vastatrix* wiped out the coffee plantations of Ceylon.

Had rust not destroyed the coffee trees in the 1880's, the English would likely still be using coffee by the hundreds of millions of pounds per year. As it is, tea is now the national stimulant, and the English, Irish, Scots, and Welsh consume half the tea produced in the world. The British now drink nine cups of tea to one cup of coffee, and the art of brewing a fine cup of coffee, it is said, has been entirely lost by the cooks of Britain.

What of the future?

The prospect of a far greater disaster hangs over the great coffee-producing countries of the Western Hemisphere which now grow 90 per cent of the world's crop. The rust fungus, since 1870, has spread its spores eastward to the Philippines and westward to Africa. There, on the west coast of Africa, these spores ride the winds, ready for any opportunity to cross two thousand miles of ocean to the coffee plantations of the New World. Nor do the *Hemileia* spores depend solely on some vagary of the winds to reach South America. They could easily be transported by the fast jet aeroplanes, in the upholstery of their cabins, or in the luggage or clothing of the passengers.

These fungus spores did reach the West once, but most fortunately, a wise and trained man was ready for the invasion. When the rust suddenly appeared on the island of Puerto Rico, in 1903, Mr. O. W. Barrett, an alert plant pathologist, spotted the disease and by drastic action speedily destroyed the fungus before it could become dispersed.

If the rust spores ever enter the coffee lands of the South American continent, and if the disease is able to spread beyond control, people in the Americas may have to take to tea, too. For if ever coffee rust devastates the bulk of the Brazilian and Colombian plantations, the price of coffee will soar beyond the means of the average man. One would have to be invited to a millionaire's breakfast table to enjoy a cup of the world's finest stimulating drink!

7 “He Who Rules the Land Rules Me’

BANANA DISEASES

Some said it was an apple!
Others said it was not!

> The serpent said to the woman,
> “ ‘Yea,’ hath God said, ‘Ye shall not eat of every
> tree of the garden?’ ”
> And the woman replied,
> “We may eat of the fruit of the trees of the
> garden: But of the fruit of the tree which *is* in
> the midst of the garden, God hath said, ‘Ye
> shall not eat of it, neither shall ye touch it,
> lest ye die.’ ”
> And the serpent said,
> “Ye shall not surely die:
> “For God doth know that in the day ye eat
> thereof, then your eyes shall be opened, and ye
> shall be as gods, knowing good and evil.”
> And when the woman saw that the tree *was* good
> for food, and that it *was* pleasant to the eyes,
> and a tree to be desired to make *one* wise, she
> took of the fruit thereof, and did eat, and gave
> also unto her husband with her; and he did eat.
> And the eyes of them both were opened.

The people of the North Temperate Zone characteristically interpreted the “fruit of the tree which is in the midst of the garden” to be an apple, which was the commonest fruit of Europe and one certainly good and “pleasant to the eyes”.

"No!" said the Prophet in the Koran. "The tree in the midst of Eden was the banana tree!"

"No!" said the legend of the Middle Ages. "The tree in which the serpent coiled and hissed his temptings was the banana!"

That the banana was the "Tree of Paradise" cannot be said with certainty, but its fruit was well-known long before the Europeans became Christians. The sages of India were eating bananas, bunch on bunch, to give them wisdom when Alexander drove the Eastern hordes before him as he crossed the Indus in 327 B.C. Likenesses of bananas carved in stone decorated the great, ornate buildings in ancient Assyria and Egypt, centuries before the birth of Christ.

It was Linnaeus who, after studying the evidence gathered by the scholars of the Renaissance, called one branch of the banana family, namely the varieties of plantains, *Musa paradisiaca* (banana of paradise). The edible banana he called *Musa sapientum*, or banana of the wise men.

Of the two fruits, apples and bananas, the latter is by far the better buy for the housewife. Apples contain 290 calories per pound, bananas, 460. In fact, bananas top even Irish potatoes in energy-producing starches and proteins and, of course, they contain a considerable amount of sugar, too. Rich in minerals, the banana is also an excellent source of vitamins A, the B complex, and C. If a star rating were used to denote each vitamin content of the common fruits, the banana would get a three-star rating for vitamin A, compared with the apple's half star.

"An apple a day keeps the doctor away" probably refers to the tendency of its cellulose roughage to keep one regular. However, a brief survey of medical texts and of standard medical practice will show that even here certain digestive defects, a touchy colon, or a celiac condition* call not for apples, but bananas.

One thing is certain, however: if man had his beginning in the hot tropical part of Asia or Africa, then one of his staple foods must have been the banana. Some botanists of today think that man peeled his first ripe banana some time back in the late Pliocene era—a million or so years ago.

The seedlessness of the banana seems to indicate man's long cultivation of this plant, although it could have been brought about by natural hybridizing when pollen from several species fertilized the female flowers. Scientists found that when distantly related plant species are crossed, the offspring are sterile.

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* A chronic nutritional disturbance in young children characterized by defective digestion and utilization of fats and by abdominal distension, diarrhoea, and fatty stools.

To propagate the tree that produced this seedless fruit, man made use of its corm—the large underground reproductive structure that is covered with scalelike, protective "leaves". Each corm contains several buds, and so it can be cut into several "bits". Each bit, when planted in good soil, will grow into a full-grown tree in about ten months. After the tree bears fruit it dies and is replaced in the next growing season by a sprout that grows from the corm. Therefore the banana plant, by producing numerous shoots from its underground corm, afforded primitive man an easy vegetative way to propagate a little Garden of Eden in his own back yard.

In the banana, eleven chromosomes make up a set. A diploid is a plant with two sets of chromosomes in each cell. A triploid has three sets, and a tetraploid has four. Altogether, there are three hundred and fifty distinct banana varieties from seven different chromosome groups —two diploid bananas with twenty-two chromosomes in each cell, three triploids with thirty-three chromosomes, and two tetraploids with forty-four chromosomes. As triploid and tetraploid plants tend to be larger and more vigorous, it is only natural that man has chosen the stronger clones to cultivate.

Most of the prized bananas of the world are triploids, and "Big Mike"—the Gros Michel banana—is at present the most valuable. Big Mikes hang in grocery stores from San Diego to Nome, Alaska, and from Miami to Goose Bay, Labrador, filling the air with their delectable fragrance. In fact 63 per cent of the world's exported bananas are of the Gros Michel kind. This clone is a big and very vigorous plant that bears pale pink flowers and heavy, symmetrical bunches of fruit. It is thought to have been native to Burma, Thailand, Malaya, and Indonesia. Only comparatively recently did this variety spread to Africa. It came to the Western world about 1820—to the island of Martinique, where it got its French name Gros Michel. From Martinique the Big Mikes were carried to Central and South America.

Two other clones—the Cavendish, which is widespread throughout the cooler subtropics, and the Mysore, an Indian banana—account for most of the rest of the banana trade.

Ready for a big surprise?

It is not Central America with its banana republics, nor South America, that produces the most bananas. It is Africa. Australia and the islands of the Pacific produce 500 million pounds of bananas annually, Asia eight thousand million pounds, the Americas thirteen thousand million, and Africa nineteen thousand million, making a grand total of forty thousand, five hundred million pounds. The reason one never hears of the huge African production is that 90 per cent of the starchy African bananas are roasted and eaten by the producers themselves. In fact 85 per cent of the world's bananas are consumed within the countries that grow them. The greatest exporters of bananas are the republics of the two Americas that lie between the Tropics of Cancer and Capricorn. Almost four thousand million pounds of green picked bananas are sent by fast train or boat to the retailers of the temperate zones of the two American continents.

Starting a banana plantation is not a simple enterprise. First, select a few hundred or a few thousand acres of land, low-lying, humid land, not farther from the equator than fifteen hundred miles north or south. Then go to the nearest bank and borrow some money. Next, buy or lease the land from the owners, absentee or otherwise, or from the government of the country. Hire a few score workers at one dollar or so per day. Buy matchets, axes, and some hardy mules. Have the workers throw up some leaf-thatched houses. Buy enough food and sundry other supplies to last for a few months.

Probably by now you will have to return to the bank and borrow some more money.

After consulting the agricultural experts of the country, bring in some of the best "bits" of the most suitable bananas you can find. Set your men to slashing down the jungle underbrush. Buy at least one tractor that is "unmirable" in the worst of swamps, plus trenching and diking equipment to go with it. Don't forget fuel for the tractor—and for the mules. Instruct your men to plant the sets in neat rows, about four hundred to the acre, in well-drained soil under the rotting debris left after the slashing operation.

Now go to the bank again and borrow more money.

Send your men through the new fields to fell the larger trees, which will be able to rot in the damp tropical weather. About now, if you have not done it before, hire a medical team to organize first aid and set up a temporary hospital. Buy plenty of aspirin, quinine, and anti-venom for everything from sore heads to malaria and snake bites. Keep sending your men through the fields to slash down the ever-present jungle weeds, until the huge leaves of the young banana plants have time to spread out like great feather dusters. These gigantic leaves will make enough shade to inhibit further jungle growth.

Set your men to clearing between the rows of plants that by now, in three months, are taller than your head. Buy enough materials, ties, rails, and rolling stock to construct a system of tramways. Have your men build workshops, storerooms, jetties, and the like. Buy some fertilizer, rich in nitrate, to replace that which is leached out of the soil by the heavy tropical rains.

If you wish to be sure of getting your bananas to market, buy an ocean-going freighter, and make sure that all the marketing arrangements with the banana dealers in the importing country are completed. Be certain that you, or your overseer, can tell the very hour that the delicate green fruit should be cut. Be sure, too, that you have enough skilled cutters and backers hired to get the bunches from the trees without bruising.

Go to the bank and borrow more money.

By now, it is about ten months since planting time, and you will be too busy to worry any more about money. You will pay all the wages, the fuel bills, the repair bills, the medical bills, the wharfage bills, the demurrage charges, the brokers' commissions, and so on, numbly but excitedly—for the days of the harvest are upon you.

In due time you will receive letters containing cheques, notices of accepted drafts, and other forms of payment for the tons and tons—perhaps as many as ten tons per acre—of the golden fruit that has been bought by millions of customers with a hankering for bananas.

Now go to the bank and start a savings account!

A word of warning: forget about the savings account if you have neglected to hire a real banana man to act as an efficiency expert who will think of the hundreds of little things, and big things, too, that by carelessness or ignorance have not been mentioned, that can ruin your land, foul up the smooth workings of the plantation, and bring you to quick bankruptcy.

Among the greatest hazards that confront banana growers are two diseases that can transform a living plantation to a dead loss in a few months. The first plague to strike the banana lands was the Panama disease, or banana wilt. It was every bit as catastrophic as wheat rust or late blight of potatoes. This disease was first mentioned in agricultural bulletins from Hawaii sixty years ago. Soon after, the disease appeared in the Panama plantations and spread quickly from field to field. Since it is caused by a soil fungus (*Fusarium oxysporum cubense*), it was probably carried on tools, the feet of workers, and in or on banana corms imported from infested plantations. Scattered outbreaks of the disease then occurred in all of the banana republics. By 1925, Panama disease was solidly established in the soils of most of the banana-growing countries of the Western Hemisphere.

There in the soil the fungus lurks, waiting for months or even years until it encounters a banana rootlet. If its hyphae can follow up through the root tissue into the corm, the banana plant is doomed because the Fusarium fungus invades the stemlike cylinder of the banana, travels up the xylem cells, and invades the food-carrying phloem and food-storage cortex. Part of the damage comes from raiding the food-storing tissues of the plant, the remainder from the toxins that are released and carried upwards to the leaf, where they injure or kill the photosynthetic cells.

The symptoms of Panama disease are sudden and startling. The tree's twelve to fifteen gigantic leaves yellow almost overnight, and in a day or two they wilt and buckle where they join the false stem of the banana. The hanging, withered leaves soon turn brown, and finally the whole banana plant crumples to the ground. If any fruit has formed on the plant it will ripen irregularly, producing stunted, starchy-tasting fruit that is unmarketable. Within a few months, a prosperous plantation is often turned into a wasteland.

Since the fungus lives hidden in the soil, not every secret of its underworld life is known to man. However, partial controls have been found. A method of silting and flood fallowing was discovered in the period from 1925 to 1935, which drastically reduced the incidence of Fusarium in the soil of the banana lands. Prior to this method there was absolutely nothing for the grower to do but to move on, clear new jungle, plant again from healthy "bits"—often brought in from hundreds of miles away—and bear the expense of establishing a new plantation.

Silting the fields and flood fallowing was a relatively simple operation if the banana farm was on flat bottomland. One simply had to breach the dike and let the river flow over the land in the rainy season, or bring water in ditches to the infested fields from farther upriver.

When the depth of the water was from two to five feet, the dikes could be closed and the fields kept flooded. Flood fallowing for even six months allowed successful cropping for another five or six years before the soil population of the Fusarium fungus would build again to epidemic proportions.

Of course, diking, trenching, and flooding are expensive. Moreover, flooding can be used only when the subsoil contains enough clay to be impervious, and when there is a feasible way of maintaining the level of water on the field during the whole flood fallowing period.

The use of resistant clones of bananas is by far the best solution to the problem. For instance, in Brazil, the French West Indies, parts of Africa, and Australia, where the Cavendish variety is grown, there are no appreciable losses to this disease. These bananas are closely related to Gros Michel and are highly resistant to Fusarium wilt. In Jamaica, the change from Big Mikes to other resistant varieties, such as Lacatan and Robusta bananas, rescued a waning industry. A stepped-up banana breeding programme might result in a resistant type of Gros Michels; but until the banana producers of the other Caribbean and Central American countries also switch to resistant varieties, it seems likely that many extensive moves to virgin banana land will continue to be necessary.

At almost the same time that flood fallowing was proving effective against Panama wilt, a new and virulent fungus *Cercospora musae*, swept into the world's banana fields from somewhere out of the vast Pacific—all the way from Java, some say. It struck first in 1913 at the Gros Michels in the Sigatoka Valley on Fiji. By 1925 the new banana disease had invaded Australia. Then it backtracked across the equator and burst into the banana lands of Southeast Asia. In 1933 the first spores of the new disease came to the fields of Trinidad, and in 1936 the sickness destroyed the plantations of Jamaica, Honduras, and Guatemala.

Wherever the disease appeared, the result was the same: utter destruction of bananas. The simple peasant workers stared at the terrible devastation. To them, only a belch of hellfire from the maw of a charging beast could have wrought such havoc, so they called the new disease "The Green Dragon". However, to the banana experts and to the plant pathologists who rushed to the rescue, it became known as "Sigatoka" or, simply, "Leaf Spot".

The advent of Leaf Spot seems very gentle at first. Faint yellow spots appear on the leaf surface, and these gradually elongate into streaks that follow the parallel lateral veining of the leaf. The streaks rapidly enlarge, the centres becoming red-brown. Surrounding these spots are bright yellow areas where the leaf cells are already dying from the fungal toxins.

After a month the tempo of the disease accelerates alarmingly; whole patches of the long, green leaf turn brown and die as if the fiery breath of some invisible dragon has seared the banana leaf. As any new, tender leaves shoot up through the central cylinder, the Sigatoka spores—both the asexual conidiospores and the ascospores that are produced sexually inside the diseased spots—are splashed on or wafted to the epidermis of the young leaves.

The conidiospores are produced in chains or brushes by special fruiting threads or hyphae, but the ascospores develop in saclike structures or asci and there are usually eight ascospores in each ascus.

As with many other fungi, the conidiospores are produced in astronomical numbers during wet, windy weather, while the ascospores, produced later during the dryer weather, are shot out of the fruiting asci when dews wet the leaf surface. These ascospores of Sigatoka are carried upwards by the rising air currents and lodged on the lower surfaces of the second or third leaf.

No matter which kind of spore pushes its infection thread through the stomata on the young leaves, the progress of the disease is the same. A trained observer, however, can tell which type of spore infected the leaf, for the conidiospores cause spotting to occur in a line pattern, while the ascospores cause tip spotting. The disease is particularly destructive in periods of wet weather, heavy dew, and temperatures above 65 degrees Fahrenheit. Plants in poorly drained and sour soils are hardest hit. Mixed stands, susceptible and nonsusceptible, or bananas grown in the cooler subtropics are little affected.

In diseased plants, the fruit fails to set or develop satisfactorily. The mature bunches fall and will not ripen. On immature bunches, the bananas suffer from severe stunting so, although flavour is not affected, the small size of the fruit makes it unmarketable.

Unfortunately, most of the prized bananas used for raw consumption are very susceptible to Sigatoka, and as yet only chemical controls are feasible. The chemical most used is the old standby, lime and bluestone —the famous Bordeaux mixture—applied by portable sprayers on small farms or by a network of permanent sprayers, fed by pipelines, on the larger plantations. The pipes to carry the spray are low to the ground, and before the weekly or bi-monthly spraying begins, the workers attach long hoses to nozzles on the pipes. Then the blue-white fog of Bordeaux mixture billows through the dark green foliage. The spray is carefully played on every plant and soon the leaves, the very ground, and the workers themselves are splattered by the blue-white wash.

Lately an oil spray has been employed with even better success. This spray is laid down by helicopters or aeroplanes as a light mist that covers the banana leaves with a spore-killing film.

A programme to breed and select resistant clones of bananas goes on day by day and week by week with small success, but great promise. So far, Gros Michel females, with thirty-three chromosomes per cell, are being crossed with wild pollen-bearing males of the *Musa acuminata* species having twenty-two chromosomes. Even with the best of care and attention the process is a wasteful one, for Gros Michel females are largely infertile, one or two seeds per bunch being all the return a plant breeder can expect. Of these seeds, usually 80 per cent are not viable, 12 per cent produce plants that are unsuitable, having fifty-five or more chromosomes and only 8 per cent are tetraploids with forty-four chromosomes that might germinate into satisfactory banana plants.

These artificial seedlings are tested by planting diseased tissue, Panama wilt inoculum, along with them. If the young plants show some resistance to Panama disease, they are tested for Sigatoka by the simple process of not spraying. If the members of a clone pass these tests, they must then be examined for even-ripening, goodkeeping qualities, wastage behaviour and, probably most important of all, taste. Though there is great hope among banana men, no clone artificially produced has so far passed all the tests with perfect scores.

"You'll never know how a banana tastes until you try one!" That is what every Yankee sailing man of the eighteenth century told his folks when he got back from a cruise to the tropics. And no landlubber ever did know, until a day in 1804 when the captain of the schooner *Reynard* took a gamble. He bought thirty bunches of green Cuban bananas, and —glory be!—he managed to sell them when he docked at New York. During the next sixty years, a tiny, intermittent dribble of inferior red bananas from the Caribbean Islands came up to the United States on clipper ships.

The first importing company dedicated solely to the banana trade was established at the end of the Civil War. It failed, however, when the French, by paying higher wages, lured the banana workers away to dig at the great "Cut" that eventually became the Panama Canal.

Two men, a sea captain, Lorenzo D. Baker, and a railroad builder, Minor C. Keith, working independently at first but pooling their efforts towards the end of the century under the leadership of a Boston man, Andrew W. Preston, did more to build the fabulously rich banana trade than any others. Keith, in spite of the heartbreak of seeing three of his brothers and thousands of his workers die from yellow fever, went on to build a railroad from Limon on the Costa Rican coast to San José, the capital. After he had completed the section across the flat, swampy land near the coast, he started some banana farms that, he hoped, would provide some business for the railroad and thus help to pay maintenance costs. By 1882, Keith had plantation after plantation growing bananas and had expanded his operations into the nearest republics. He had title to ten thousand acres in Nicaragua, ten thousand acres in Panama, and fifteen thousand acres in Colombia. His stems were going into the United States markets at the rate of 2,500 per month. Bananas saved Keith and his railroad from financial disaster.

Meanwhile, Captain Baker had been hauling bananas from Jamaica since 1870. By 1879 the ship that he captained, the *Jesse H. Freeman*, was carrying bananas to Boston, twelve thousand bunches at a time. This venture was successful only because the Freeman's auxiliary steam engine below decks cut her running time from Jamaica to Boston to eight or nine days from the usual eighteen. Thus, the bananas reached the Boston market a few days before they ripened, and the dealers were able to sell them before they rotted.

The banana business went so well as a sort of sideline that Baker and Preston, who had sold many of the stems on commission, thought it could be built into a profitable, independent enterprise. So, in 1885, they and nine other businessmen incorporated the Boston Fruit Company, with Preston as sales manager.

Boston Fruit never used one drop of red ink in keeping its accounts. In fact, business was embarrassingly good, and they began to run out of bananas to sell. Jamaica and the islands could not supply enough. Who had more bananas? Minor C. Keith, through his three trading and banana companies, was able and willing to fill the need. So successful was this intercompany cooperation, that in the nineties other companies flocked into the business. In fact, sixteen million stems, each bearing 200 to 225 bananas, were brought into the United States annually by over a hundred banana firms. That huge total represented all the bananas that were available for trade in the Caribbean area, and the Yankees were eating them all.

Competition soon weeded out the unlucky and inefficient operators, and by 1899 there were only twenty-two banana firms left. The largest of these, Boston Fruit and Keith's companies, merged to become United Fruit. This new company was a colossus standing astride six banana producing republics and the great islands of the Caribbean. It owned one hundred and twelve miles of railroads and two hundred and twelve thousand acres of land, of which sixty thousand acres were in bananas. By that time the company had greater fleets of fast refrigerated banana ships than many a maritime nation, and more ships were added. In 1910, United entered the European market by purchasing the large British firm, Elders and Fyffes, and after buying out Cuyamel in 1929, it had become the major banana broker in the world. The present day United Fruit Company represents the merged businesses of over twenty-one banana firms that once operated independently. In 1956, it sold forty million stems from its Latin American plantations to the banana-hungry people of North America and Europe.

When Baker, Preston, Keith, Sam Zemurray of Cuyamel, and other businessmen began to see that solid, permanent fortunes could be made from the handling of one of the world's most perishable fruits, they made plans to expand their operations. But they found the inhabitants of potential banana-producing countries sadly lacking in "gringo savvy". The social and industrial structure of these republics rested, with the exception of Costa Rica where 90 per cent of the people are of pure Spanish descent, on the shoulders of the many Indian tribes which were still ruled by superstition and tribal law. There was, it is true, a large percentage of mestizos—ladinos, as they called themselves—who identified partly with the small, ruling faction of full Spanish descent and partly with the "indios" of the villages.

The mestizos, as well as the indios, lived the simple life in their native villages, where most of their needs could be filled by the nearby jungle and a small plot of land. A few dollars represented a fortune. If a bottle of aguardiente was forthcoming at the village dance, well and good; if not, a shrug of the shoulders and some *guaro*, a fiery raw drink made from sugar cane, would do. This reply of a Carib Indian chief to Minor C. Keith's request for men to help build his railroad and plant bananas was typical:

"I am honoured by the visit of so distinguished a visitor. The Carib men are honoured that such a great man asks them to go and work in the strange land—Costa Rica. The women are doubly honoured that the distinguished guest needs the strength and wisdom of their men to help him. But my people have been fishermen and boatmen since time began. And they will remain so till time ends."

For these reasons it was most difficult for the new banana industry to get workers, but the lure of the *yanqui* dollars was often all the bait that was needed. Besides, Minor C. Keith had not spent millions of dollars and suffered sorrow and hardship in order to give up. By his perseverance and with his likable personality, he succeeded in catching the admiration of the people of Costa Rica and Honduras, soon procuring both workers and various government concessions for his banana farms.

Using similar tactics, Lorenzo Baker interested the people of Jamaica. Later, Samuel Zemurray moved from New Orleans down to Honduras and bought up some of the best banana-producing land in the world. In 1892, Zemurray had come from Bessarabia to America, where at the age of fifteen he helped in his uncle's store. He recognized the great future in bananas, and in 1905 went to Honduras where he bought land along the Cuyamel River. Zemurray had all the qualities of the other two banana pioneers—he was a risker, a thinker, and a doer, and a crackerjack farmer besides. However, he knew that if he was to succeed in this venture, he would require some government concessions and guarantees: permission to build a railway, no rise in taxes, and above all the exemption of Cuyamel from import duties on materials needed to build his railway, wharves, and the like.

As luck decreed, Zemurray had bought his land just at the time when Honduras was threatened with bankruptcy. The president, Miguel Davila, was already negotiating with American bankers for a loan. The bankers finally agreed to the loan, but only if their appointed agent could have control of Honduran custom collections. Sam Zemurray knew right then that his "bananas had ripened on the tree". It was most unlikely that the American bankers would consent to the abrogation of customs for one individual company—and a shaky one, to boot. However, Zemurray was not alone in his uneasiness. Many patriots, the influential General Manuel Bonilla among them, saw the proposed control of customs by a group of foreign bankers as an unholy plot against their national independence. As if it were a shining road, Zemurray saw the course to take. He loaned Bonilla enough money to buy a fast yacht and some machine guns and rifles. These purchases were used so effectively that when Bonilla was sworn in as president, Zemurray received every concession he had asked for.

Zemurray risked millions on the irrigation of his banana farms. He employed selective pruning, the propping up of heavy fruit stems, plus every other good farming practice that was effective. Moreover, he had the great advantage of having his headquarters in the tropics and under his personal guidance. Cuyamel was soon shipping bananas of better quality than United. In fact, critics among United's stockholders were wont to say that the way their company was directing its operation from Boston was often not much more effective than would be the efforts of an Alaskan hermit trying to run a bawdy house in Panama City. Cuyamel sold more and more bananas, and its stock rose higher and higher. Prospects looked so bright for Zemurray's company that United Fruit purchased seventeen thousand Cuyamel shares.

Sam Zemurray and his Cuyamel Company began to eye a lush bit of land along the Honduran-Guatemalan border. It is entirely possible that this new desire on Cuyamel's part came from apprehension caused by the already devastating inroads of Panama disease in the plantations of Costa Rica, Nicaragua, and Panama. We do not know with certainty. Nevertheless, Zemurray received a land grant from the Honduran government, although both parties knew full well that the land in question had been under dispute for more than half a century and that it was vehemently claimed by the Guatemalan government. Troops were sent into the area by both disputing governments and some blood was spilled.

Since United Fruit had had a firm understanding with the Guatemalan government that it would get concessions and grants to develop this disputed strip of borderland when and if the award went to Guatemala, some observers said that the affair illustrated how a rich and powerful foreign corporation, by enlisting the support of rival governments, could create political frictions and incite violence. Others saw the affair as an example of how rival governments of the area often sought the financial support and influence of rich North American companies to further their aims and bolster claims.

Until 1929, Cuyamel and United Fruit stayed neck and neck in their race to bring better bananas to the American market. Then news that Zemurray had sold his thriving Cuyamel Company—land, railways, ships, and all—for a cash consideration plus United stock worth at least thirty million dollars, startled the banana trade and left United Fruit as one of the world's largest corporations. It now had more land area under its control than many a king could boast of, hundreds of miles of railroads, a whole fleet of steamships, and nearly a hundred thousand workers and their families.

Then for the second time disease came. It was not a new disease; it was Panama wilt again. This time the fungus had crept into the new plantations—those that were started on virgin soil to replace the ones devastated before.

The first round of losses to Panama wilt came in the period from 1915 to 1923 when the total acreage in bananas in four of the republics —Costa Rica, Panama, Colombia, and Guatemala—dropped by forty thousand acres. By 1930, the planters in those four countries had dug enough banana sets into rich virgin soil to bounce the acreage back in three of the four republics. Costa Rica, however, where the majority of the banana farmers had small holdings, showed a steady acreage decline. The small owners just could not spend the money necessary to flood fallow their land or buy new land on which to start again.

Honduras did not follow this loss trend because there the great banana companies were, or had been, straining to make this republic into a real "Banana Land". There, Zemurray of Cuyamel had pioneered in flood fallowing, and his company, as well as United Fruit and its chief competitor, Standard Fruit and Steamship Company, had cleared and planted until they were farming ninety thousand acres of the yellow fruit in 1925.

Altogether, in its second attack on the banana crop, the wilt reduced the total cultivated land in plantations in all five republics by fifty thousand acres from 1930 to 1935. Production for export in those republics dropped by about half a million tons during the same period.

Scarcely had the remedy for the Panama wilt been found when that new scourge, leaf spot or Sigatoka disease, struck like one of the plagues of Moses. Production declined sharply as plant pathologists and plantation managers scrambled for a control. And they found it in the old fungicide friend of man, Bordeaux mixture. But spraying bananas is not like spraying beans. The spray must shoot up ten to twelve feet to cover the leaves thoroughly. High pressure sprayers—expensive ones—or aircraft did the job as well as could be expected.

Like all the other fungi that bother man, these two have not been beaten. They have only been brought under a measure of control—for the time being, perhaps always. The grim possibility remains that the process of killing off the weaker fungus spores will leave a few stronger ones to generate more virulent races. So far, however, banana growers have learned to live with the Panama wilt and leaf spot that still exact an annual toll estimated conservatively, from 1915 to 1960, at about 7 per cent of the gross value of the world's banana trade—over a thousand million dollars. Normally, about seven bananas are eaten on the banana homestead for every one that is shipped abroad. So while the rest of the world chafed at the higher cost of bananas in the years that the Panama wilt and Sigatoka leaf spot devastated the banana farms and plantations, many poor people in the banana republics suffered genuine hunger.

There are other ways in which these banana diseases have left their mark with special attention focused on the Central and South American republics.

"He who rules the land rules me" is almost an immutable law of nature and of society. Both the Panama disease and Sigatoka tended, through their depredations, to shift the control of the land from the small owner to the large and—in the case of the United Fruit, Cuyamel, and Standard companies—absentee owners. Absentee landlords have always been and will always be somewhere between a scourge and a nuisance. Through their agents, the plantation managers, the banana companies that were near failure tried to counter every decline in production with larger land grants and other concessions, such as water rights or right-of-ways for their railroads, from the government in power.

Many of the agents of the banana companies were brash newcomers from the North with little or no regard for the customs or rights of the local inhabitants. They often turned to the use of unauthorized methods of persuasion—bribery, propaganda, and intimidation—that would be not only immoral but illegal back home in the States. No doubt many of the stockholders and directors would have been astounded, even horrified, if they had known exactly what was going on between their agents and managers and the rulers of the banana republics. True, the companies' fears of banana crop failure were based on cold facts. It was clear by 1930 that in Cuba, Jamaica, Mexico, British Honduras, Nicaragua, and Dutch Guiana the local banana industries were on the decline. Today some of these countries have virtually no banana trade, while production in others has been reduced to a tiny fraction of its former volume because of Panama wilt and Sigatoka disease.

But the company managers were shortsighted. The mounting ill will of the Central Americas, generated by such underhand or threatening methods, gathered like huge thunderheads, menacing everything that the banana pioneers had ever planned.

Of course, there was and is another side to the coin. The companies under criticism claim that through their normal operations and through concern for the workers' welfare, they have benefited both the country and the people. For example, in Guatemala, where United Fruit owns or controls almost 2 per cent of the country's land area and about 1 per cent of the agricultural land, that company contributed about twenty-one million dollars in 1955 to the economy of the republic. Since the total Guatemalan agricultural output was two hundred million dollars, United Fruit, from 1 per cent of farming land, produced 10 per cent of the total agricultural wealth. In addition, it paid almost two million dollars that year in taxes.

The wages paid to the banana workers averaged $2.40 per day on United Fruit farms as compared with $1.20 per day on coffee farms. Moreover, the company provides free and decent housing, with toilets, electricity, and garden areas on the majority of its farms. Modern schools, with teachers who are nationals of the host country, have been providing free education for children during the day and for adults at night. United Fruit is also very conscious of the health problems in this tropical country and has supplied hospital and medical facilities, the workers contributing to the upkeep of these services through deductions from their wages.

In 1953, certain events took place which involved the United Fruit Company and the Guatemalan government. Early in that year President Jacobo Arbenz redistributed over a quarter of a million acres of the United Fruit Company's former Pacific holdings and 175,000 acres of United's Atlantic holdings. This policy was popular with the common people.

On June 18, 1954, Guatemala was invaded by a force that assembled in Honduras, and Guatemala City was bombed. President Arbenz appealed to the United Nations Security Council, and on June 20 the representative from Guatemala charged that for some time before the invasion his country had suffered from an intense propaganda barrage as a preparation for this aggression:

> "This," President Arbenz said, referring to the propaganda barrage, "started by the United Fruit Company and other monopolies and sponsored by the State Department of the United States, has tried to show Guatemala as the spearhead of communism and an instrument of Moscow."

The proposal by Brazil and Colombia to refer the matter to the Organization of American States was vetoed by the Soviet Union on the grounds that Guatemala would be "squashed under the foot of the aggressor" while the matter was being so referred. Fighting continued, and on June 28 the Guatemalan government collapsed. President Arbenz resigned, and Colonel Diaz, head of the invading forces, took control. In 1955 the new Guatemalan government restored the United Fruit holdings to the company.

As a result of this revolution and its aftermath, there was a considerable amount of misunderstanding and some bitterness between Guatemala and the United States. However, thoughtful men on both sides agreed that the United States government should exert a measure of control over large American companies operating in the banana republic.

Consequently, in 1954, the United States Department of Justice filed a civil anti-trust action against the United Fruit Company. This suit was terminated by "consent decree", with the company agreeing to divest itself by sale of all its stock in International Railways of Central America not later than June 30, 1966. A new company would be formed to take over enough of the United Fruit Company's holdings to make it a genuine competitor. The United Fruit Company also agreed to discontinue a long list of objectionable practices that might stifle healthy competition.

Natural events lend themselves less readily to man's control than do political changes. Thus, so long as Panama disease and leaf spot infest banana plantations—and that may be forever—the economy of the banana republics will be influenced by their presence. The conditions imposed by these diseases will tip the balance in favour of those who can afford the costly equipment and practices needed to keep the two fungi under reasonable control. Will the production, handling, and sale of bananas slip further into the hands of large, wealthy corporations, or will banana growing and trade be carried on by co-operatives that allow even small growers to pool their finances and have a greater say in their own affairs? The answer to these questions may determine not only the economic make-up of the banana republics but their political complexion as well.

The Strength of Forty

Everyone connected with the banana industry will agree that some of the banana diseases that were native to Southeast Asia could have been kept out of Central America by effective quarantine regulations.

One of the first known edicts aimed at preventing disease from entering a port or a state was issued by the Doge of Venice in A.D. 1403. Black Death, so named because its victims turned a dark purple colour before dying, had swept over the world many times, in some places killing up to a third of the population during one epidemic. In the late 1300's, the cities of Italy and of all Europe suffered several times from this most terrible of all man's diseases. Consequently, when the Venetians began to expand from their island-dotted lagoons to the mainland, and when their maritime trade in the Mediterranean, especially with the Levant, reached new proportions, their doge, Michel Steno, ordered all ships entering Venice from foreign ports to lie at anchor in the lagoon for forty days before disembarkation.

The growls of the sea captains and the howls of their crewmen could be heard from one end of the Adriatic to the other, but the edict was rigorously enforced. And because the Italian word for forty is "quaranta", "quarantina" or "little forty" became the name for similar restrictions or regulations—quarantines. The value of quarantine regulations was gradually recognized by all the civilized world, and the restrictions have been extended to combat the spread of disease even from house to house.

The idea that quarantine regulations would aid in preventing the spread of plant diseases was not adopted anywhere in the world until about 1870, almost 500 years after the Venetian doge's edict. Germany imposed an embargo in 1875 against potatoes from Canada and the United States. Importation of tubers or of potato plants was prohibited to prevent further entry of the Colorado beetle, commonly called the potato bug. In the wormlike or larval stage, these beetles have a voracious appetite and feed on the leaves of the young potato plant; if left undisturbed for three or four days, they will defoliate and kill the plant.

In the United States quarantine regulations against indiscriminate importation of plants were instituted in California in 1881, but again they were aimed not at a plant disease but at an insect, the gall louse. The federal government of the United States, acting on a bill introduced by Congressman James S. Simmons of New York, passed the National Quarantine Act of 1912 to exclude insect pests and plant diseases from the country. Other progressive countries of the world developed their own systems of control, and now the United States Department of Agriculture considers the quality of pre-shipment inspection done by trained officials of about fifty nations to be adequate. Therefore, the United States will accept plant shipments from those countries if they have been certified as disease free.

It is true that the system of quarantine, with its bothersome regulations, is restrictive to both trading firms and to individuals. However, the entry of exotic plant diseases may be so devastating to a nation's agricultural economy that quarantine of suspected plants, or fruit of such plants, is mandatory. Everyone, even the casual tourist who is stopped at the border of a country, state or province, and forced to surrender the fruit or vegetables he is innocently carrying, must recognize the need for quarantine regulations. The authorities who impose the restrictions realize that if one serious new pest is introduced into the country, the cost of eradication or control can run from millions to thousands of millions of dollars per year. In many cases no control system can be found that is effective, so the nation must bear the cost of perpetual damage. Sometimes, as in the case of white pine blister rust, the cost is cumulative as more and more seedlings are affected during the hundred or more years needed to bring that crop to maturity.

It might seem to a person with pessimistic views that the whole quarantine system is bound to fail in the end. The spores or other inoculum of the plant diseases are so tiny and their numbers so great that the most sharp-eyed inspector must miss detecting them on some of the many plants and packing cases, ships and aeroplanes that cross the borders of a country each day.

But man has many allies in this fight. Sometimes temperature is enough to kill the pest; sometimes an ocean, a desert, or a range of mountains is an effective barrier to the spread of the alien parasite. The air currents that carry the fungi spores are often erratic and bring the spores down to earth or deposit them on mountain peaks. The rain and the snow clean the air so that spores travelling across a sizable body of water or a desert never reach the green pastures on the other side. Moreover, the spores, and even the fungal pests in their adult stages, are quite fragile and often die easily from the slightest environmental change.

Another preventive lies in the nature of the parasite itself. Very few of them have more than one host, and if that host is not growing in the new area, the disease pathogen cannot adapt in time to get established on an alternate host.

The quarantine authorities of the United States are heartened by the fact that a great many plant diseases attacking the crops of the world are not found inside their nation. Among pathogens which attack potatoes, 93 have never got into the United States. Of 111 rice diseases, 90 of them are absent from the rice fields of the United States. And further studies show that a great number of destructive plant diseases have not yet been found anywhere on the North American continent.

Everyone directly connected with agricultural quarantine will agree that the movement of pathogens from one country or state to another can be curtailed if all plant propagating materials are effectively inspected. But the quarantine inspectors must have public co-operation, for their careful work can be easily undone by the thoughtless and the sly persons who smuggle seeds, tubers, bulbs, root stocks, or other plant parts from one place to another.

Lately quarantine areas have been established that are very effective in the fight against virus pests. When a shipment of propagating stock arrives, it is planted in the quarantine plot. If clear of pests, it is then forwarded after forty days in isolation. When the shipment bears some hidden and destructive disease, it is destroyed and the soil in which it grew is sterilized.

Much evidence is available to show that many terrible plant diseases were carelessly introduced into the North American continent from Europe and Asia, some appearing even after the principle of quarantine was established. Hop mildew came in about 1890 and has ruined the hop-growing industry in the eastern and midwestern parts of the continent. Hop culture has been chased by this fungus across the country to the Pacific Coast. What will happen there depends partly on effective quarantine regulations.

Asparagus rust came from Europe in the 1890's and potato wart in 1912. The people of the Gulf states have been fighting citrus canker for over fifty years. Flag smut came from Australia during World War I. Dutch elm disease was accidentally introduced in 1930, and recently the Lombardy poplar canker was brought to North America and has already destroyed this popular shade tree in many eastern regions.

In spite of isolated breakdown in method, the principle of quarantine must be observed if more food from the world's farms is to reach the mouths of the hungry. A trained plant pathologist best serves his country and humanity when he detects and stops a dangerous pest before it can become established.

8 Vulcan's Victims: One Life Equalled Eight Pounds

S.A.L.B. OF THE RUBBER TREE

During the first half of the nineteenth century, the economy of the United States was not as steady as it is now. Businessmen, anxious to expand and to take advantage of the new opportunities of acquiring wealth in a growing nation, speculated freely, and the economy tended to swing wildly from depression to boom. During the decade beginning in 1830, at least two distinct market deflations caused numerous bankruptcies. One of the ruined firms belonged to a hardware manufacturer and his sons who did business out of Philadelphia.

In 1830, the firm of A. Goodyear and Sons went broke. They could have escaped the debts that swamped them by going through legal bankruptcy proceedings, but one son, Charles, wanted to retain some valuable patents, so he chose to shoulder the debt burden of the firm himself. Charles Goodyear soon discovered that the life of a debtor in the United States in the 1830's could be that of a jailbird. During the decade he was in and out of prison several times.

At that time everyone in America was talking about a wonderful new material, India rubber. While he was in New York City on one of his many unsuccessful trips to raise a loan, Charles Goodyear became fascinated by a rubber life preserver he saw in a store window. He hurried into the store and asked to examine the article.

He bought the life preserver, but not to use; it had a defective valve, and he was sure he could invent a better one. If everything worked as he hoped, he might be able to re-establish his father's firm.

Goodyear scarcely recognized the Roxbury India Rubber Store—where he had bought the rubber life preserver—when he went back to New York that summer. The July sun was blazing into an empty store window. The array of rubber coats, rubber shoes, and rubber hats that had been there in the spring was gone. Goodyear entered the store with a sinking heart. Perhaps the Roxbury Rubber Company had gone bankrupt, too.

When the manager wryly assured him that the store was open for business, Goodyear's eyes brightened and he proudly unwrapped the parcel to show the perfect valve he had invented for rubber life preservers. In reply, the manager led the way to the back warehouse. There, in a putrifying pile, lay all the rubber goods of the company, oozing and rotting. Charles Goodyear gasped. He knew that his valve would be useless until a weather-resistant rubber was developed. And there, in the stench of rotten rubber, Goodyear's grand dream was born. He, Charles Goodyear, would find a "cure" for the rubber so that it would neither melt in the summer sun nor freeze in winter.

For the rest of his life, a quarter of a century, Goodyear never spent a waking hour without a scheme or a plan about rubber running through his mind. In his obsession, he spent all his money and then pawned his household goods for more. But his single-mindedness kept him driving ahead—his single-mindedness, plus tooth-gritting determination, his courage in the face of criticism and insult and, above everything else, the help and comfort of his wife, who was determined that her husband should have every chance to succeed.

Goodyear had spent some time in debtors' prison before 1834, but in the years to follow, his impatient creditors had him in jail so often that he whimsically called it his hotel. But such was his perseverance that he set up a workbench in his prison cell where he mixed and rolled rubber. He tried rubber with carbon, rubber with turpentine, rubber with anything. In the spring of 1835, he borrowed money from a friend and set up a manufacturing plant in his living room to make rubber boots. His wife and the family, down to the youngest child, laboured with him. The shoes were beautiful, dyed in brilliant colours, embossed, shining. But June came hot and July came hotter. Goodyear's shoes melted away in the heat, and his dreams went with them.

Any sensible man would have give up, but Goodyear persevered. The day he tried magnesia, he knew that somehow, some day, he would get his perfect rubber. The magnesia and rubber mixture held up until next summer, when hot and humid weather brought ruin for the third time. By pawning his wife's few jewels and linen, he raised money for rent and food for his family and then once again left for New York.

At the New York Fair he won an award—and with it the first money for all his work—for a magnesia-lime-rubber mixture that felt like leather. He even made and sold some rubber goods, but the buyers soon found that any acid ruined Goodyear's "cured" rubber.

The "Rubber Man", as he was now called by his erstwhile friends, persisted. A lucky accident showed him that nitric acid would cure the rubber better than anything he had tried, and he secured a patent for the process. A New York man put up thousands of dollars, but the financial panic of 1837 wiped out the newly established rubber business. Goodyear and his family lived the rest of that year in the abandoned rubber factory and ate fish from New York Harbour.

By 1839 Charles Goodyear was set up again and even had a government contract to manufacture rubber mailbags in Boston. The bags were sturdy and strong but they, too, melted in the summer heat. Goodyear's affairs were at rock bottom, and his children would have starved that autumn of 1839 had it not been for generous farmers who gave them milk and permitted them to sneak half-grown potatoes from their gardens. Then, when even strangers began to call Goodyear stupid and useless, the great discovery came.

One day in early 1840, Goodyear, ignoring the taunts and insults of his neighbours in the general store, was arguing that his new sulphur and rubber mixture might be the answer. Suddenly a sticky fistful of the stuff slipped from his fingers and fell on the red-hot stove. Raw rubber, or any mixture of it, would have melted and bubbled as a wad of chewing gum would today; but the sulphur and rubber mixture simply charred. As Goodyear scraped the hot rubber from the stove, he knew that he had the answer he had sought during the last five years: sulphur when mixed with raw rubber and heated was the "cure".

Those years of desperate striving had ruined his health, but he went on with thousands of experiments to get the proper proportions and the proper heat treatment. As his efforts came ever closer to completion and to real success, Goodyear planned to make a multitude of rubber products. And he did make rubber dishes that his family ate from. He wore rubber vests and rubber hats. He dreamed of rubber ships and rubber sails and rubber flags. Even now, over a century later, some of his ideas turn up as "new" uses for rubber.

From 1840 on, as eager businessmen came to Goodyear for help and he sold rights to manufacture rubber goods, his fortunes rose. His family began to live affluently, and although he often had to protect his rights in the courts against some dishonest manufactures, there was plenty of money in the Goodyear purse.

He moved his family to England, at that time the greatest industrial nation of the world. Four years after his discovery he applied for a British patent, but he was about a month too late. An English inventor, Hancock, had ingeniously worked out the process after examining some of Goodyear's own cured rubber samples and secured his own patent. Hancock's term, "Vulcanization of Rubber", remains the common designation.

Hancock offered Goodyear half his British patent rights, but the great inventor chose to spend a large sum to contest the case in court. It was the greatest mistake of Goodyear's life, for he lost the lawsuit, and thus the British market was closed to him.

Goodyear then left London for France, and for a while he prospered. At the great fair in Paris he showed a vast array of rubber goods; the very pavilion in which they were exhibited was made entirely of rubber. It was in France that he won his highest award, the Cross of the Legion of Honour, but it was pinned on his chest in a dingy cell of a French debtors' prison. His French patent had been cancelled, and once again his creditors had pounced. Somehow, he raised money to get out of jail and to return to America.

His spirit was strong but his health was ruined, and he died in 1860 in a New York hotel room. He left his family nothing but debts. Through the years he had deliberately avoided any close connection with the young and thriving rubber companies which were using his patents because he wanted to keep all his energy for inventing. He never regretted that decision. He once said in an answer to critics: "A man has cause for regret only if he sows and no one reaps."

At least a thousand years before Charles Goodyear, the jungle peoples of the Western Hemisphere were using rubber in a raw form. Two genera of trees in Central and South America yield a milky juice, latex, from which a satisfactory rubber can be made. One of these is the Castilloa, a giant of a tree towering high above the lesser trees of the Central American jungle. Any single tree of the two species of Castilloa will yield gallons of latex at one tapping. The other genus is Hevea and any of its four species, of which *Hevea brasiliensis* is the best, will give a finer quality of natural rubber than the Castilloa. Since no Hevea trees grow wild north of the Isthmus of Panama, the Mayan rubber either came from the Castilloa tree or was obtained by barter from the distant jungle tribes.

Throughout the world several other plants produce a rubber-bearing latex. The Russian dandelion, the *Taraxacum kok-saghyz*, has rubber in its thick, long tap root. The rubber tree, *Ficus elastica*, grows in India, and the three Landolphia vines of Africa give a kind of rubber, though it is inferior to the Hevea product. From a bush in Madagascar and a Mexican weed, guayule, rubber can be extracted. In all there are about fifteen plants in the world whose white sticky latex contains enough rubber to make them commercially valuable in an emergency. The average Hevea tree will produce four pounds of dry rubber annually, and especially selected high-yield trees will give up to ten pounds per year of the finest para rubber, a grade named after the Pará district of North Brazil.

The growing of Hevea trees in plantations, a hundred or more trees per acre and stretching for miles, has been impossible in either North or South America because of a virulent fungus parasite, *Dothidella ulei*, whose olive-green spores spread rapidly throughout thick stands of trees and cause South American Leaf Blight. Not only is this blight the most serious disease affecting *Hevea brasiliensis*, but it is one of the most destructive plant diseases that is known. In destructive power, S.A.L.B., as the plant pathologists call the disease, ranks with late blight of potatoes and coffee rust. If a single leaf of a rubber tree becomes infected with S.A. Leaf Blight the disease develops quickly. In a few days the conidiospores of the fungus develop and are released from the sick leaf. These spores are sufficient in number to dust all the brown, shining flushes of young trifoliate leaves that hang in groups of fifteen or twenty on the terminal twigs of the tree.

Each infecting spore sprouts a germinated thread that quickly enters the young leaf tissue. Inside the leaf, the fungus spreads into the photosynthetic cells and robs them of their rich food supplies. Within a week, aided by the warm humid weather of the jungle, this seething fungal mass thrusts out its fruiting hyphae, and billions of olive-green conidiospores cover the doomed tree's leaves. If the trees are close together, the fungus spores are carried by breezes or splashed by torrential rains onto nearby foliage. But in the jungle environment, a distance of a few hundred yards provides protection, since the quiet air lying below the high crown of the tropical forest cannot transport the relatively heavy S.A.L.B. spores very far. Thus, so long as the stands of trees are kept separated, the 500 million Hevea trees in Brazil, Bolivia, Peru, and Ecuador are safe from an epidemic of South American Leaf Blight.

That is not to say that the inroads of the disease are minor. To be sure, as the leaves of the rubber tree become older, they develop a hardened cuticle which resists infection, despite some spots of diseased tissue; and the fully mature leaves, with their thoroughly toughened cuticle, are not susceptible at all. Nevertheless, the disease also infects tender stems, young flowers, and fruit. The olive-green spores are produced continuously for two or three months, or until the weakened trees shed their morbid and tattered leaves. Leaves not seriously affected remain on the tree, but function with reduced efficiency. When the diseased leaves fall, the tree puts out new ones, but after a few defoliations, the whole tree begins to die. At the end of the conidial or acute stage of the disease, the S.A.L.B. mycelium changes and begins to produce two types of tougher spores that are borne inside spherical fruiting bodies, within whose protection they can withstand periods of drought. Although in the known range of S.A.L.B., from southern Mexico all the way to central Brazil, the fast-germinating spores keep the disease endemic, the other two types of spores might well be the vital forms that could remain alive for the time it would take to cross the oceans to Africa and southeastern Asia.

The history of rubber began long before the Mayans, the Incas, or the Aztecs ever saw the "bounding stones" of rubber. It must have started in the mightiest river system of the world—the Amazon.

This great, hot, humid plain became the native domain of the area of Europe, with an average rainfall of seventy-two inches annually. No wonder that the Amazon at its mouth is one hundred miles wide—that even fifteen hundred miles back towards the Andes it runs strong and deep, two to five miles across, in its first rush to the sea. Each of its half-dozen main tributaries carries more water than almost any other well-known river in the world.

This great, hot, humid plain became the native domain of the rubber tree. The habitat of the *H. brasiliensis* species lies like a huge bow hundreds of miles thick curving south, with the silver Amazon forming the cord of the bow. This area is so immense that even though they are sparsely distributed—one or two per acre—more than 500 million *Hevea brasiliensis* trees grow here. To the north countless millions of the *Hevea benthamiana* grow between the river and the Caribbean Sea. Here, in one of the hottest and most humid climates on the face of the earth, the rubber trees flourished—as long as they were not crowded together where the S.A.L.B. fungus might reach them.

The first men to learn about rubber were the ancient primitive tribes that lived in these Amazon jungles. These wandering savages were the first to see rubber-bearing latex that flowed white and thick from the great trees with the dark, glossy leaves. They knew how to collect the latex, but they found few uses for it. Even the Mayans, one of the most civilized groups in the last millennium, did little with the substance except to fashion comic shoes and many religious images, and to make the great, ten-inch rubber balls with which they played a game called pok-a-tok.

This game, semi-religious in character, was played on huge enclosed courts, sometimes almost twice as large as a modern football field. On the side walls two stone rings were set thirty feet above the playing floor, and the players endeavoured to put the ball through the ring by striking it with knee or elbow, or bouncing it off the hip. Since the opening in the ring was little larger than the diameter of the ball, goals were rarely scored. Usually, the player who scored a goal received a spectacular reward—all the jewels and all the clothing of the spectators. But often the priests ruled that members of the losing team in an important game be sacrificed to the gods.

Somehow, by countless accidents or patient trying, the Indians had learned all but one of the secrets of the rubber tree and its latex. They had learned to wound the tree's smooth bark and catch the thick, milky juice that oozed from the cut. They had learned to curdle the latex and dry it over a fire, discovering that the best smoke for the coagulating process came from burning a kind of nut that grew in the same steamy jungle as the rubber tree. And they had formed moulds for fashioning shoes, syringes, breastplates, and other useful things.

When Christopher Columbus and his unwilling sailors first saw the primitive Indians in Hispaniola, these Indians had dozens of rubber artifacts in their possession. Four and a half centuries ago, Cortez and his conquistadores, too, saw the wonderful rubber. These Spaniards, from regal governor to sweating soldier, stretched and bounced this marvellous product of the new world; but rubber to them was merely a curiosity.

For two and a half centuries the peoples of Europe knew little, nor did they seem to care to know more, about curdled latex—the caoutchouc, the useless play-stuff of the New World jungles. The Old World finally learned of rubber through the work of two Frenchmen, Charles Marie de la Condamine, an intense, scientifically-minded explorer, and François Fresneau, an engineer. La Condamine, in 1734, headed an expedition sent by the French Academy to explore the equatorial regions of South America. The next year he sent back to Paris a few rolls of the blackish, resinous substance. Fresneau, an adventurer as well as an engineer, was so interested in some rubber articles the Indians had brought him from the Pará region of Brazil that he set out from Cayenne in French Guiana to learn all he could about the fascinating new substance and its origin. He recorded his findings in a memoir that la Condamine read to the French Academy in 1751.

The new substance, though it interested many men, received little attention for several decades. During the next half-century, however, Portugal began to import rubber articles from its Brazilian dominions, and new rubber-bearing plants were discovered in Africa and in India. About this time, Priestly gave the exotic caoutchouc its English name of rubber because it would rub out pencil marks. The French still retain the word, caoutchouc.

In 1808, the Portuguese king and his government fled to Brazil to escape the menace of Napoleon, and the colony's long-closed ports were opened to the commerce of friendly nations. By 1820, the first pair of ill-fitting rubber boots arrived in the United States, and in 1823, five hundred pairs of these boots were unloaded in Boston. Although crude and high priced, they nevertheless became so popular that by 1850 over half a million pairs were coming into the United States annually, all of them fashioned, like the rubber syringes and numerous other objects, by the Indians of Brazil.

The rubber articles were certainly no bargain. As Goodyear discovered, if they were not stored in a cool place during the hot summer weather they melted into a sticky mass, and they could not be used in cold weather because they became hard and brittle. No one, not even the Indian artificers, had discovered how to keep rubber from being so "touchy" to the temperature.

In the 1820's a Scotsman name Charles Macintosh discovered a method for overcoming the warm weather stickiness of rubber by simply making a cloth sandwich. Two layers of cloth stuck together by rubber applied in a naphtha solution made a fortune for Macintosh and his new partner Hancock, and Macintosh's name passed into the English language as a synonym for raincoat (mackintosh).

Then in 1840 Goodyear and Hancock got patents from their respective governments for the vulcanization of rubber, a relatively simple process of mixing and heating sulphur and raw rubber. Blended in varying proportions and heated to exactly the right temperature, the sulphur combined with the rubber to form a substance, the exact nature of which still puzzles chemists. Vulcanized rubber can be made as elastic as the raw latex, or almost as hard and durable as bone by varying the amount of sulphur: the less sulphur, the greater the elasticity. With this almost limitless potential, rubber caught the fancy of world investors.

"Rubber means wealth!" said the white man.

"Rubber means slavery!" said the red man.

"Rubber means death!" said the black man.

And at one time or another all three sayings came true.

The first raw rubber came to American ports in 1800 in great, stinking, hundred-pound biscuits that the skippers threw into the lower holds for ballast. By 1860, the year of Goodyear's death, the United States was importing three hundred tons annually, the demand mounting through the latter half of the nineteenth century as the uses for rubber became almost as diverse as man's activities.

Shortly after the middle of the nineteenth century a new "toy", the bicycle, caught the public's fancy. At first this new vehicle jounced along on steel tyres, but soon these bone shakers were replaced by solid rubber tyres that only jarred the kidneys. The pneumatic tyre was invented in 1890. With the coming of the horseless carriage, and the larger pneumatic tyres it required, the demand for rubber in a few years became a runaway, insatiable obsession. By the turn of the century, Brazil's exports of rubber had teached twenty thousand tons; fifteen years later this quantity had doubled.

It is quite easy to write of forty thousand tons of wild rubber. But to gather that huge amount was another matter. One must remember that the Hevea were scattered in little stands or single trees in the wildest, unfriendliest region of the world. And one must remember, too, that the workers of the rubber regions were simple, naïve Indians.

At first rubber traders enticed these Indians by offering them trade goods—beads, coloured clothes, firearms—that glittered temptingly but rotted or fell apart in the dripping jungle, a jungle so humid that a gun loaded with dry powder in the evening would not fire the next morning. Indian workers soon found themselves arising before the sun and hacking their way through the jungle undergrowth in the tedious work of gathering the latex from the scattered trees. Then, in the afternoon, they huddled in the curing rooms—the defumadors—of their miserable huts, searing their lungs in the acrid coagulation fumes of the smudge fires of smouldering urucuri nuts.

Day after day, week after week, the rubber workers toiled along the paths, *estradas*, which were somewhat like traplines in that the workers were given the right to collect latex along the paths of a specified territory. They gathered the latex in the morning, smoked the rubber in the afternoon, and fell into their hammocks at night, red-eyed from the smoke of the smudges, grey-black from the slime of the jungle floor, exhausted from their drudgery. Living alone, far away from his home village, subsisting on a diet of farina, jerked (sun-dried) beef, corn, and salt, many a rubber worker decided to quit. But when he approached his *patrao* he found that he was in debt for his food and supplies and must keep on working to pay what he owed. The result was that the rubber worker found himself indentured for life. If he ran away, his chances of finding his way back to his home were small indeed compared with those of getting an arrow or a bullet in his back from unfriendly tribes, or falling prey to some parasite or predator of the jungle. The inevitable result was that the majority of the rubber gatherers of the great Amazon basin endured hopeless misery.

But they did run away in ever-increasing numbers until the *patraos* working for the rubber barons were ordered either to get them back or to get new workers. The *patraos* thereupon led gangs of toughs into the tribal villages where they seized the men, women, and children and forced them into slavery on the *estradas*. Those who dared to resist or escape were punished without delay. Some were flogged until their backs and buttocks were flayed then turned loose in the jungle, where they staggered away and died, masses of maggots consuming their ruined bodies. Others had their heads cracked with rifle butts or were blasted with shot when they ran or resisted. The little ones were lucky. They died suddenly with their brains splattered on some handy tree trunk.

How was it on the great river itself, in the newborn boom town of Pará that became a dazzling metropolis, or in the roaring city of Manaus midway upriver to that hell hole, Iquitos, in Peru? Some of the rubber barons who lived in one or another of these cities owned literally thousands of *estradas*. They pocketed a good share of the profits from the rubber gathered by all the miserable wretches who stumbled over the jungle paths. They, their hangers-on, and their women lived luxuriously. Some, when drunk, lit their cigars with banknotes and bathed in champagne; others imported everything that money could buy, floating docks at forty million dollars, complete opera houses with companies and orchestras from Europe, and fancy dresses, diamonds, and rubies for their paramours.

That was how man tried to meet the demand for rubber from 1860 to 1910 in South America. Thousands upon thousands of Indians were enslaved, surrendering their lives—slowly, in body-wracking toil, or quickly, by blows, floggings, machete strokes or gunfire. The great god Rubber claimed his victims, and his will was enforced through the *patraos* and their gangs of thugs. Behind these inhuman atrocities lay the greed of the rubber barons and the innocent connivance of the investors in the far-off capitals of the civilized world.

Africa was another continent to feel the effects of the demand for rubber. There, the story of rubber began shortly before the quest of Henry Morton Stanley for Dr. David Livingstone. In a strange way the story of rubber in Africa is bound to the achievements of exploration and the organizational work of Henry M. Stanley.

The Congo basin, although it had been discovered four hundred years earlier, remained one of the least known areas of Africa until the explorations of Stanley in 1876–77. There was a great and growing interest in all Europe concerning this dense jungle region with its elephants, ivory, and, perhaps, other sources of wealth. All kinds of men were interested in the Congo, men of high and low estate: and one who was most intrigued by what he heard from Stanley was Leopold Coburg, better known as Leopold II, King of the Belgians.

Late in 1878, Leopold organized a committee to study the "Haut Congo". The committee engaged Stanley to return to Africa, where he founded a number of posts and secured certain concessions from the native chiefs. In 1885, the Conference of Berlin recognized the sovereignty of the committee, known later as the African International Association. The Congo, with Leopold as personal sovereign, was declared open to the trade of all nations. The king ruled his new domain with the understanding that after a stated period the land, its inhabitants and, of course, the profits, would be transferred to the Belgian government.

Leopold's enterprise succeeded beyond his wildest dreams. The profits from the Congo made him one of the richest men in Europe. And most of the money did not come from ivory, nor diamonds, nor gold —but from rubber.

By the early 1900's, ugly stories began to drift out of the Congo concerning King Leopold's private estate. Finally, in 1903, the British Foreign Office commissioned Sir Roger Casement to visit that territory and make an investigation. Casement's Congo Report in Africa No. 1 was one of the most famous "White Papers" ever published.

To understand the events that took place in King Leopold's Congo estate, one must realize that the sources of the rubber found there were not trees as in South America. Rubber in Africa was to be found in three species of Landolphia and in other vines. The rubber was extracted by pulling down the vines and cutting notches along their length to start the flow of latex. Then the latex had to be coagulated in the leaf cups by boiling it or by adding acid fruits. In the grass and scrub land, the Landolphia species also had an underground rhizome, a tuber-like stem that had to be pulled up yard by yard. In this plant the latex-bearing vessels were in the bark, and rubber was extracted by pounding with wooden mallets until the bark was reduced to dust; the reddish rubber remained.

The whole process seemed so simple, and the rewards so easy to obtain from Leopold's traders, that at first the Congo natives were delighted. They almost fought for the privilege of getting baskets from the traders for carrying in the rubber. But when the whole vile mess was over and done with, the old men said, "We did not know—we never understood—we could not guess what it all would turn into in time to come."

All the old pursuits were soon neglected. All the time-proven ways of life were forgotten. All pride of tribal self-sufficiency disappeared in the race to trade raw rubber for the gaudy cottons and glittering beads and fiery liquor. The tribes moved across the land from old territories to new ones searching for the rich clings of rubber vines.

Soon the tribesmen grew tired of the labour; they wished to return to their old homes and their old ways of life. But the king, their trustee and their master, Leopold of Belgium, wanted rubber; he had to have rubber. He would get the rubber, no matter what the human cost, and even though African rubber was inferior to South American, its price was rising in the world's markets.

Leopold borrowed heavily at home, using the funds literally to forge a black army from the warlike tribesmen of the Congo. He hired agents to trick the native chiefs into signing "treaties" that stripped them of their powers. Then as the king's grip tightened on the large and well-populated Congo, the pressure on the natives to collect rubber increased until the whole population became virtually enslaved. Every able-bodied man of the tribe worked from sunrise to dark seven days each week, under the cruel and murderous eyes of the black mercenary army, to collect his quota of the tribe's "latex tax".

These black men of the Congo did not submit to slavery as readily as had the meek redmen of the Amazon. They took up their spears and fought; against the superior army of Leopold, they often gave better than they got. But the result was inevitable and the rebels were punished. Countless thousands were tortured and mutilated. Tons of human hands and human genitals were dumped in front of the king's agents to prove that the recalcitrants had been dealt with. The rebel women were raped, and they and their children were either killed or flogged till their blood and their urine soaked the packed clay of the village compound. The wretches who were still alive worked themselves into semi-exhaustion to get out the king's rubber. Weakened, starving, and without hope, they died by the millions from sleeping sickness and smallpox, or other virulent diseases, and their bones were scattered through the jungle.

It is impossible to imagine the human misery spawned in the Congo from 1890 to 1908. Then, forced by world revulsion at the atrocities revealed by the British investigation, Leopold agreed to cede control of the great river basin to the Belgian government. During his fifteen year trusteeship, the population of the Congo dropped from twenty-five million to ten million—a million lives a year to get out sixty thousand tons of the reddish rubber of the Congo. The equation: one human life equalled eight pounds of rubber!

The race for Africa's second-grade rubber did not end with the take-over and clean-up in the Congo. The traders and the concessionaires simply moved into the French Congo or any other area where the jungle vines could be milked of latex and the natives could be enticed or beaten into gathering the wild crop.

This gory race for wild rubber, so that an ostrich-like Victorian society could glide through its world in minimal discomfort—and discomfiture—might have gone on indefinitely, but for a masterful act of smuggling. As far back as the early 1800's the Dutch, British, and other planters of the world were thinking of rubber as a plantation crop. Castilloa trees were tried in Mexico and Cuba without success. *Ficus elastica*, tried by the Dutch in Java, proved a failure. The British thought that Hevea might be the best tree to try, and they were right. In 1875, Sir Henry Wickham, a planter on the Amazon, heard of the British interest in Hevea trees and offered to supply seed at fifty dollars a thousand.

Wickham and his Indian helpers gathered from the jungle floor seventy thousand fine, heavy seeds after they were thrown out of the dehiscent capsules of the great trees. He packed them carefully and got them away on a handy British ship. Had the Brazilian authorities at Pará guessed the cargo that was slung between the steamer's decks, the game would have been up. He knew that the seeds would have to reach Kew Gardens without delay because their viability would diminish daily on the voyage. But the ship cleared, and the greatest smuggle in history—since the Mullah took the seven coffee seeds out of Arabia—came off successfully.

About two thousand transported seeds germinated, and the seedlings were sent to Ceylon. There they did well, as well as some others secured by a man named Robert Cross. Seeds from these two sets of Heveas were used to start the plantations in the Malay Peninsula in 1881 and in Java some years later. Growth of the rubber plantations in the East was slow, however; by 1905 only one hundred and seventy-five tons of rubber had been produced from the fifty thousand Hevea trees on the British plantations. But world prices having soared to a dollar and a half a pound, investors surged into the market to support the new and promising industry. By 1908 there were seven hundred and fifty thousand acres in the Asian plantings, and the price was still rising, reaching a fantastic $3.06 a pound in 1910. This impetus spurred further activity by the investors and planters, and by 1915 there were two and a half million acres in rubber.

Now came a great multitude of small investors to throw their savings into rubber stocks, and the boom gathered momentum. The wild jungles of Malay, Borneo, and Sumatra became gigantic checkerboards of new plantations. In 1913, the eastern tonnage was about equal to the world's wild rubber output; but by 1919, there were three hundred and fifty thousand tons of plantation rubber produced, compared with fifty thousand tons of wild rubber. The tremendous increase in natural rubber from the eastern plantations scarcely kept up with the demand for tyres by the automobile industry, but finally in the Roaring Twenties the flood of natural rubber from the plantations caught up to the demand and the price dropped to a few cents. The boom in plantation rubber was over, and so was the unholy need to enslave and kill in the Congo and the Amazon.

Would not most of the misery, the degradation, and the horror have been avoided by the simple method of establishing Hevea plantations in South America, Mexico, or Central America, as was done in the Far East? The course of history, especially for the countries and peoples directly concerned, would have been vastly altered if such an addition to Western horticulture had been accomplished. Though men from Villa Bella to Veracruz dreamed of growing rubber trees, planning and labouring to establish plantations of Hevea, these efforts always failed, as we have seen, because the olive-green spores of the South American Leaf Blight lurked in the nearby jungle and blasted the young trees. Thousands of attempts by humble Central American farmers, huge United States corporations, and proud Spanish *hacendados* of southern Mexico came to nothing: the plantations would flourish until the deadly S.A.L.B. spores won their inevitable victory.

Even when some rubber planters used Castilloa seedlings, which were not affected by S.A.L.B., the results were disappointing. These trees gave a good supply of fine rubber but, because of the Castilloa's interconnecting latex vessels, the whole tree was drained whenever the bark was properly cut. Since it took two or three months for the latex vessels to be refilled, the Castilloa latex could be harvested only two or three times a year. Although some Mexican estates had plantings of up to a million Castilloa trees, the determination of the *hacendados* was not stirred enough to make the ventures successful.

The first large plantation in the Western world was set up right in the homeland of the Hevea on the Tapajós River in Brazil, less than fifty miles from where Wickham gathered his seeds. There, in 1927, the Ford Motor Company began to plant at Fordlandia. By 1934, Ford had planted over eight thousand acres in Hevea trees, two hundred to three hundred to the acre. But before the last trees were in the ground, the first were sick and dying. The operation was deemed a failure, and the whole project was transferred down the river to Belterra. By 1939 there were twelve thousand acres of rubber trees on the new plantation.

For a time this plantation showed great promise. A new technique had been developed and used on the trees planted at Belterra. The scientists budded resistant tops to the young rubber saplings from clones of trees that had survived the S.A.L.B. disaster at Fordlandia.* But the disease spores proved too virulent, so the Belterra project also failed. Ironically, Brazil, the home of the rubber tree, harvesting twenty-five thousand tons of wild rubber yearly, with a government that continues to encourage rubber production and plantings, today is a heavy importer of raw rubber from Asia.

Only in the plantings in the Caribbean island chain, from Cuba to Puerto Rico, are the Hevea trees safe from the deadly leaf blight. However, because the climate is not quite right for this jungle tree, these plantations are not successful, either. Plantings in Guyana (formerly known as British Guiana), Panama, Costa Rica, Guatemala, Honduras, and other Central American countries so far have been either unsatisfactory projects or they have failed absolutely.

Nevertheless, it would be surprising indeed if from the efforts of thousands of ingenious men, nothing good would result. Probably the best thing to come from the struggle to establish plantations in the West has been the man-made, triple-budded, super rubber tree with the hardiest root stock, the highest rubber-yielding stem, and a top with blight-resistant leaves. Not only is this jerry-built tree a good thing, it is, indeed, a grand thing, one that might be the only "invention" capable of saving the eastern plantations.

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* This mother tree is sometimes worth as much as $50,000, far more than the price of a prize-winning Hereford bull.

Since the spores of the South American Leaf Blight remain alive for just a few hours, there is little danger now of their being a potential menace to the East Asian plantations. But in the near future, when supersonic jets are in operation, the fungus spores could be transported by accident, still alive on arrival, to infect the Hevea stands in Malaysia, Indonesia, and the islands of the Eastern Archipelago.

What could happen if the disease was carried into this new territory would be speculation. Experts in rubber and various government officials agree that without total enforcement of quarantine and the most stringent eradication programme, not only of the diseased trees but of all neighbouring trees, every rubber plantation in the Far East could be lost in a single year.

Today a programme of tri-clonal budding is supported by the planters of Asia and their governments. If the programme can replace the disease-prone descendants of the trees of Wickham's collection before S.A.L.B. reaches the Far Eastern plantations, then the world's source of natural rubber will be secure. But, if that programme fails, nothing could save the eastern plantations.

By Christmas, 1942, the Japanese armed forces had overrun British Malaya, Dutch Sumatra, Java, and the rest of Southeastern Asia. Their spectacular military success constituted a far greater blow against the Western Allies than did the capture of the Philippines: the West lost control of well over ten million of the eleven million acres that made up the cultivated rubber forests of the world. Only plantations in Ceylon and India remained in Allied hands, less than a million acres of Hevea rubber trees that annually could produce at best little more than fifty thousand tons of raw rubber.

In Europe and North America, home and countryside were scoured to find used rubber. Everything from old tyres to old girdles was collected. Even with this desperate salvage effort, the supply of raw rubber in the West fell short of the demand by well over a thousand million pounds. The pressure to collect wild rubber increased in direct proportion to the military pressure exerted by the German and Japanese military forces, for the armies of all the fighting nations rolled on rubber. The Germans had large synthetic rubber plants turning out hundreds of thousands of tons yearly, while the Japanese, after 1941, had natural rubber in abundance.

Looking ahead, the Allied governments realized that it would take their chemists and business geniuses at least two years to build a synthetic rubber industry. Therefore, the American government set up the United States Rubber Development Corporation, which hastened to sign an agreement with the Bank of Brazil to get rubber from the upper Amazon country.

The plans of the Rubber Development Corporation were straightforward. The United States was to supply the money to pay the Brazilian workers, and the Bank of Brazil was to assume responsibility for getting out the rubber. The aim of the Rubber Development Corporation was to gather at least fifty thousand tons of wild rubber annually, but the amount borne out of the backcountry on the heads of the *bravos*—workers—or in the wallowing boats or by plane would not fill the needs of the Allied armies for more than a few days. And critics charged that the American government had spent six thousand million dollars! The president of the Rubber Development Corporation set the cost at a mere hundred million dollars, or two dollars a pound.

Recruiting rubber gatherers was an easy task. There had been a severe drought in Brazil in 1942, and the desperate and starving people were glad to join the great "army of rubber workers" that grew and grew until it was said to number fifty thousand. These greenhorn rubber men, under the control of their *patraos*, rowed their way up the Amazon to gather rubber. The *patrao* taught inexperienced workers how to slash the bark of the rubber tree and how to catch and smoke the milky latex. Then he left each *bravo* to sweat in the jungle heat.

Wild stories reminiscent of Brazil's colonial period filtered out from the Amazon country in 1944. Thirty, forty, fifty thousand rubber gatherers had died in a vain attempt to get enough rubber for the use of the Allied armies! But investigation soon clarified the record. These tales were exaggerations; only eighteen thousand *bravos* had been recruited; but seventeen thousand had left their bones in the tangle of the Amazonian jungle.

This rubber was indeed costly. Seventeen thousand dead workers and scarcely twenty thousand tons of rubber!

Well, why not forget about the wild rubber trees and the tame ones, too? Let the chemists produce synthetic rubber for the world's needs. This solution would surely dispose of several problems, especially the nasty ones that arise when scheming men exploit simple men. Moreover, synthetic rubber in quantity would eliminate forever man's nagging fear of losing the eleven million acres of plantation Hevea trees to South American Leaf Blight.

The chemists have done their part well. They began the study of rubber and its complex molecules long before the first seeds reached Kew Gardens from Henry Wickham. In 1860, this research had progressed far enough to isolate from rubber the substance "isoprene"—C_5H_8.

By 1880, the rubber chemists had learned that isoprene molecules could be joined to form a gigantic, long, coiled molecule, that acted like a spring; while it resisted stretching, it snapped back into its curled-up position whenever the pulling force was released. This process of making a huge molecule by joining many small ones is called polymerization. Then in 1882, W. A. Tilden found that isoprene could be obtained from turpentine.

The British authorities granted the first patent for the synthesis of artificial rubber in 1910. By 1912, a factory in Britain was making from two to five pounds of synthetic rubber per day. During the First World War, Germany produced two tons of synthetic rubber per day. Over twenty years later, with a force of brilliant chemists trained to overcome all difficulties, five German synthetic factories turned out Buna rubber made from butadiene for the Third Reich in quantities up to four hundred tons daily, in spite of fierce Allied bombing attacks.

In contrast, America was synthesizing only about seven tons per day in 1939, a figure that had increased to a paltry twenty-five tons in 1941. However, after the Western world lost control of the Eastern plantations in 1942, a stupendous effort in the United States brought the daily output from eight hundred tons in 1943 to twenty-five hundred tons in 1945. This rate of synthetic production fell off in the postwar recession, but by 1955 it had bounced to three thousand tons per day, and it has not fallen below this figure up to the present time.

Judging from the output in Canada, England, France, and Germany, and estimating how much synthetic rubber is made east of the Iron Curtain, an intelligent guess would place the rest of the total world's production at about equal to that of the United States. This would mean that the world production is about two million tons of synthetic rubber yearly.

If man had to make do with synthetic rubber, he could. Its properties are close enough to those of natural rubber to make it a satisfactory substitute in most cases. In fact, it can be made with some desirable characteristics that are not found in natural rubber. However, many of man's needs are still better served by natural rubber, and that is one reason why wild rubber is still gathered and why there are millions of acres in rubber plantations. Another important reason is cost. The basic material used in most processes of synthesizing rubber is petroleum. If all rubber were produced synthetically, it would require such great quantities of crude oil that the rise in the price of crude oil would make the synthetic method of producing rubber uneconomical.

Of course, there is one other method of manufacturing artificial rubber. The chemists can start with grain or sugar. With the help of yeasts, they can make ethyl alcohol, another basic material that can be used to construct a synthetic polymer. But grains and sugars, valuable foodstuffs, are already in short supply.

If the reader adds carefully the total quantities of new rubber produced—both synthetic and natural—and compares this sum with the amount of rubber used, he will find production to lag behind use by several hundred thousand tons. This difference derives from the sizable tonnage of used rubber that is made usable again by running it through sets of differential rollers. The resultant heating and tearing somehow revitalizes the used and worn rubber molecules, and they regain their old bounce.

And what do people do with all this rubber? Two-thirds goes to automobile manufacture. A well-equipped car has about five hundred items made entirely or partly from rubber. Pneumatic rubber tyres for cars, farm tractors and other machinery, and hard rubber tyres for some European trains, take the bulk of production. The second greatest consumers of rubber are the manufacturers of industrial products, such as rubber belting, conveyors, tubing, gaskets, and the like. Ten per cent of the rubber is used in this way. About 8 per cent is used in the latex foam industry, and the rest goes into a variety of uses—shoe products, 5 per cent; insulation for wire, 3 per cent; miscellaneous, 10 per cent. Altogether, rubber is used in the manufacture of forty thousand other products, not the least of which are the two types of contraceptives that have in the last thirty or forty years, in the Western world at least, postponed doomsday by giving parents some control over the size of their families.

No doubt the uses for rubber will multiply far faster in the future than they have in the past, and if man wishes to make full use of its wonderful properties, the Eastern plantations must be maintained at all costs. That bouncy stuff is even more popular now than when a sweating Mayan scored a ring shot in the pok-a-tok court long, long ago.

9 The Microfoes of Food

BACTERIA AND VIRUSES

The cumulative loss of man's domesticated crops to plant diseases is not all caused by attacks of fungi. Several hundreds of the thirty thousand plant diseases are caused by bacteria and viruses. Some of these diseases are fully as serious as those caused by rust, smut, mildew, or other fungi. In fact, bacteria can be considered a subgroup of the fungi proper; they are named as such in the system invented by Linnaeus to classify living organisms. Generally, parasitic bacteria live in surroundings that are neutral or slightly alkaline; thus they are pathogens that attack animal cells more readily than plant tissues. But a few of the bacteria have evolved and become suited to such acid surroundings as are found in plant cells. When these bacteria get into any part of a plant, the result is a disruption of the normal functioning of tissues, reducing the yield or killing the host plant. It may be the toxins produced in the infected cells are responsible for the sickening and eventual death of the plant.

Today, it seems incredible that only a hundred years ago no one except a French chemistry professor guessed that the microscopic one-celled plants, which we now call bacteria from a Greek word meaning "little stick", caused many diseases of man and animals. Louis Pasteur, in 1866, was investigating the diseases of wine and of the silkworm. Observing the bacteria in the wine vats and in the tissues of the silkworms, he became convinced that they caused the diseases. His hypothesis was ridiculed by many people; indeed today, a century later, most of the population in some backward countries do not know of, or believe in, the germ theory of disease.

In the 1600's, Anton Leeuwenhoek, the Dutch microscope maker, had observed with his single-lensed instruments the bacteria that exist almost everywhere in the biosphere. He saw the cocci, the round ones; the bacilli, the rod-shaped ones; and the spirilla, the spiral-shaped ones.

But he had no inkling of the roles that a few of them played in many diseases of the plant and animal kingdoms.

Pasteur's published findings in the mid-nineteenth century inspired a period of intense experimentation. Many brilliant minds were focused on the structure and mode of attack of bacteria, and it was not long until other valuable discoveries were made. In 1880, Joseph Lister made his important contribution to medical science by initiating the technique of antisepsis, a condition in which bacteria are counteracted, and of asepsis, a condition of complete absence of pathogenic bacteria. About the same time, Robert Koch established his simple but logical method of proof that a specific bacterium was the pathogen causing an animal disease. His procedure was as follows:

> The suspect bacterium must always be found in the tissues of the sick animal. It must be isolated in a pure culture and identified—measured and drawn.
>
> A healthy host of the same species must be inoculated with the same pathogen, and the symptoms of the resulting disease must be the same as in the case of the sick organism first studied.
>
> The bacteria suspected must be re-isolated from the experimentally inoculated host.
>
> The members of the re-isolated, pure pathogenic culture must be identical with those of the original culture.

However, almost two decades went by after Pasteur's work before someone proved that bacteria can cause diseases in plants as well as in animals. Even as late as 1899, Erwin F. Smith and other American phytopathologists were still in serious disagreement with German botanists on this point. Today we know that there are many more kinds of bacteria attacking plants than attacking animals, human beings included.

The man who proved that a bacterium can cause a plant disease was a remarkably able teacher, superintendent of schools, mathematics professor, professor of botany and horticulture, and university president—Thomas Burrill of the University of Illinois. Almost certainly if Professor Burrill had not been burdened with the heavy responsibilities of directing and building up a state college into a great university, he would have become one of the world's foremost plant pathologists. Professor Burrill had the brilliance of an original thinker as well as the dogged determination and thoroughness of a Charles Darwin. By applying this unusual combination of talents, he learned the source of one of the world's most dramatic and devastating diseases: the bacterial fire blight of apples and pears. This disease had swept through the orchards of the United States and Canada in the mid-nineteenth century like a conflagration, blackening and blighting whole orchards—even whole valleys—in a single night.

Professor Burrill discovered that the parasitic bacterium of fire blight was so small that ten thousand of them laid end to end would not measure more than an inch. He also discovered that the bacterium, *Erwinia amylovora,* was of the rod-shaped or bacillus type. In fact, all bacteria that affect plants are of this type, whereas bacteria that cause animal diseases may belong to any one of three types: round, rod, or spiral.

The fire blight bacteria are disseminated by splashing rain, by birds, squirrels, and such insects as flies, bark borers, and plant lice. The bacteria are most frequently—and innocently—spread by our old friend, the honeybee. These bacteria gain entrance to the tree through openings such as stomata in the leaves, lenticels in the stem, or any scratches or cuts in the bark. In the phloem tubes, deep in the bark, they are nourished by the sweet sap and, by simple cell division, they multiply rapidly and are carried to every part of the tree.

Sometimes the disease blights the blossoms, and they wilt and rot. Sometimes it kills the twigs, leaving them black and twisted. At other times, large lesions rot patches in the older leaves, or black, pocklike lesions erode the fruit. On the branches and stems, long elliptical cankers are formed, and all the living tissue in and under the bark dies. Such cankers occurring on the lower branches of the fruit trees provide a safe place for the bacteria to live during extreme winter conditions; but if the cankers spread to the stem base, they usually kill the tree.

The cankers exude a sticky ooze filled with innumerable bacteria, and these are carried away by insects or other vectors to infect healthy fruit trees. The virulence of fire blight bacteria is so great that the transmission of a single bacterium to a healthy plant will often result in the death of that plant. It would take a page of fine print to list all the plants that are susceptible to fire blight, but apples, pears, and quince have suffered the most damage.

For a long time, fire blight was confined mainly to the continent of North America. Since 1910, however, this bacterial disease has somehow been spread to such far away places as Japan, New Zealand, and Europe. It was known to exist in the Hudson River area as early as 1780. Throughout the Midwestern states of the United States, the disease caused the death of millions of trees about ninety years ago. It ruined the pear orchards of California, especially those in the San Joaquin Valley, when it reached that state in 1900. And when the disease spread to the pear districts on the Gulf Coast of Texas, it devastated them completely.

The crucial step in the control of any disease is to uncover the life history of the causal organism. Until Professor Burrill did his brilliant pioneer work, control measures for fire blight were largely ineffective, and orchards had little or no protection against the ravages of the disease. Even today, control measures serve only to minimize the damage and prevent widespread epidemics. Some of these measures, though effective to a degree, are not always practicable. The principle insect vectors may be reduced in numbers by the use of insecticides. It is helpful when other hosts, such as hawthorn or mountain ash that are near the orchards, are destroyed. Various sprays, such as Bordeaux mixture, may be used; pruning instruments should be disinfected. But probably the use of resistant varieties of fruit trees offers the most promising method of control. The unfortunate truth, however, is that once fire blight has invaded a fruit-growing area, it is there to stay, and there is an annual bill for spraying, pruning, and replanting to be paid by each orchardist.

A conservative estimate of the cost of replacing a fruit tree, combined with the cost of losing several years' yield, would come to not less than fifty dollars. Thus, the total damage done by fire blight has already amounted to hundreds of millions of dollars. This loss would have been far greater, however, if Professor Burrill had not become interested in the disease. Besides saving orchardists a great amount of money, Professor Burrill opened a new line of investigation for scientists to follow in further study of the thousands of bacterial blights and rots that still rob man of his much needed food.

In 1904, Erwin F. Smith and his colleague Charles O. Townsend found that a bacterium was the cause of crown galls, or plant cancers, that affect trees, berries, sugar beets, roses, vines, and many other plants.

The big, soft, whitish growths of this malignant disease slowly darken in colour as they choke the life of sick plants, and then spread in some unknown way to cause secondary growths on roots, stems, and even leaves of their hosts.

Crown gall has been found in the fields and orchards of every continent of the world, except, of course, Antarctica. Biological scientists have done innumerable experiments and published mountains of papers on their studies of the disease. Cell physiologists, microbiologists, cytologists—scientists who study cells—and plant pathologists of almost every country in the world have worked hard in an attempt to solve the many mysteries attending plant cancer.

Are plant tissues really similar to those of animals?

What is the carcinogen—cancer causing agent—of crown gall?

Tumours often larger than the host and weighing a hundred pounds drag down the sick plant. Is it the bacteria Smith found in the galls that initiate proliferation of normal cells until growth becomes a runaway thing?

If the cause and control of crown gall cancer can be found, will it open the way to a more complete understanding of animal cancer? No definite answers have yet been found.

Perhaps, as some workers suggest, a virus lurks in the bacterium. If so, the bacterium may act as the vector or carrier of a new cancer-forming agent. Scientists have come to this conclusion because many, many times they have found secondary tumours far away from the original tumour—and with no sign of bacteria in the secondary growth.

Plant tissues and the malignant growths of plants are more easily studied than those of animals, since plants have no circulatory, nervous, digestive, or other systems that would complicate research studies. For this reason medical researchers have been particularly eager to study plant cancers. In the vast amount of research already done, there is no proof that crown gall and animal cancer are in any way related. Nevertheless, plant pathologists and other scientists continue their research in the hope that a cure will be found not only for crown gall of plants, but also for man's most dreaded disease.

Bacteria have caused a multitude of other plant diseases. Soft rot of vegetables, blights of legumes, and a dozen bacterial wilts are among the hundreds of serious bacterial diseases. Losses have been and still are tremendous especially in tropical and subtropical countries, where the rots have probably caused the greatest part of the damage. There are white rots, black rots, brown rots, and other rots—almost as many rots as rats in Hamelin, but there is no Pied Piper to take them away.

Nevertheless, there is a watch and ward whose vigilance serves to keep bacteria and the like away. Many of the states engaged in the important citrus fruit industry impose strict quarantine restrictions on fruits arriving at their borders. Since federal inception in 1912, regulations covering the importation not only of fruit, but of seed, seedlings, plants, or parts of plants, are strictly enforced.

The citrus fruit industry is a major one, with a yearly world production of over twenty million tons. It is based on valuable dietary practice, for all the citrus fruits are rich in citric acid and that most important vitamin, C.

The grapefruit, *Citrus paradisi*, is truly a North American plant, since all investigations point to the island of Jamaica as its place of origin. Curiously, however, the parent species, the pomelo, is also found in Indonesia. The United States produces 90 per cent of the world's grapefruit crop consisting of about thirty varieties.

The common China orange, *Citrus sinensis*, and the mandarin orange are the most popular citrus fruits, followed by the tangerine, a variety of the mandarin species. The word for "orange", found in Sanskrit, indicates that the tree with the red-yellow fruit existed in India five thousand years ago. Through the centuries the word changed from "naranga" to orange, although the Spanish word still is "naranja". Some authorities state that in English the words used to be "a norange". Yet, however the name was derived, the fruit became immensely popular. One third of the world's oranges is grown in the United States, where 60 per cent of the crop is processed into juice.

The lemon was unknown to the Romans and to the Greeks, but its cultivation spread rapidly along the Mediterranean coast once it was introduced into Western Europe from the Middle East by the Crusaders. At present, Italy and the United States produce more than 50 per cent of the world's crop, but the lemon is enjoying a resurgence "back home" in the new and vigorous state of Israel.

The lime grows on a small, very thorny, tropical tree. While most varieties have a green skin, others, such as the Tahitian variety, are lemonlike in appearance. This fruit, important as a preventive of scurvy during the long voyages of the sailing ship era, was first used for this purpose by the British Admiralty. Thus English sailors came to be known as "Limeys", a term considered somewhat uncomplimentary by the average Englishman of today.

Because of the tropical or subtropical temperature requirements of the trees, the citrus groves of the United States are strung across the south from Florida to Arizona and California. In the winter of 1913–14, an observant orange grower in Florida saw that on some of the trees small cankers had formed on the fruit stems and smaller branches, and the oranges were spotted with brown, corky patches. The fruit was unsightly and unmarketable. Yellow spots on the dark green glossy leaves later changed to brown with pale halos around them. The grower knew that his trees had a new disease—he was sure of that—and he reported it to the federal plant pathologists.

At that time the United States was losing its chestnut forests. This new menace to an industry growing in importance was, therefore, more than doubly alarming, and every effort was made to discover its identity. It was quickly found to be the citrus canker disease caused by the bacterium *Xanthomonas citri*, and believed to have come into Florida on nursery stock from Japan. The disease was common at the time in Asia. By early 1915, federal and state authorities realized they must act quickly and radically if the orange groves were to survive. Inspection crews began examining the groves in Florida and Mississippi. Diseased trees were found on 515 properties in 26 counties.

As the inspectors worked from orchard to orchard their clothes were sterilized, and even the dray mules they used in their total eradication programme were made to walk through a disinfectant bath before the crews moved on. If one infected tree was found in a citrus grove, every tree was destroyed by kerosene torches. The growers gave concerted and intelligent cooperation.

The programme cost millions of dollars and the destruction of millions of citrus fruit trees. Not only were bearing trees destroyed, but because the disease infects young trees more readily than older ones, nursery plants also were sacrificed.

This is one of the major battles against plant disease that man has won. No citrus fruit trees with canker have been found in the continental United States since 1927. The last large-scale inspection, made from

1947 to 1949 and encompassing the seven southeastern states, disclosed no recurrence of the disease.

Citrus canker never did reach the extensive citrus plantations of Arizona and California. Nonetheless, continued vigilance is necessary to keep the bacteria out. In one month the agricultural inspectors at a single California port made ten separate interceptions of infected fruit that might otherwise have been carried ashore.

The whole story constitutes a triumph for—and a tribute to—the plant pathologists and their co-workers, the patient, thorough quarantine inspectors.

Ever since the 1700's, many plant diseases have been reported for which there has been no known cause. A familiar example is the degeneration of potatoes described by the English farmer, Maxwell, in 1757. The farmers called this annual lessening of the crop yield the "running out" of potatoes. Finally, and after years of observation, students of plant diseases proved that the yield was decreasing because the tubers were becoming not only smaller, but fewer.

The farmers kept insisting that the potatoes were just getting weaker, running out, and the scientists had few effective arguments against common opinion until they found the cause of the trouble. The running out was caused by a new kind of pathogen—a virus or group of viruses—which was gradually spread from plant to plant by the plant lice that are always found in potato fields. After a few years every tuber in the field was infected, and when the farmer planted his potatoes in the spring, he planted the disease with them. But it took a long time, in fact from the 1770's to 1910, to isolate the potato leaf roll or leaf curl virus.

The minute size of all the viruses allowed them to pass through ordinary filters and to remain invisible under the most powerful microscopes. Besides, the virus often seemed ghostlike in its ability to become an integral part of the host plant's protoplasm. Gradually, this "otherworldly" existence of the viruses became understood. When the electron microscope was invented, the viruses were seen for the first time as tiny spheres many times smaller than bacteria.

It is just possible there were no viruses at all in the Old World until tobacco, potatoes, and other members of the Solanaceae family were carried back to Europe by conquistadores or explorers of Mexico and Peru. Of course the evidence is flimsy; nevertheless, the truth is that more viruses use the members of the Solanaceae, or nightshade family, as hosts than any other plant family. Some viruses have the ability to exist in the form of crystals in which they remain dormant. But when these dormant crystals are put into a solution, the viruses regain their ability to infect healthy plants. And since these viruses can remain alive in crystal form for as long as fifty years, it is quite possible for them to have been brought to Europe by Columbus, Cortéz, or Raleigh, in dried tobacco leaves. Today, the viruses are widespread throughout the world, and many strains of them are extremely virulent. Of necessity, thousands of plant pathologists are at work every day to contain these new foes of man's crops.

Since 1951 a good many of the cereal biologists, especially those concerned with barley and oats, have been badly worried about the development of a strain of virus that attacks these grains. The barley growers thresh over a million tons each year. Although barley is little used for human food, it is certainly not a minor crop, a fact known to anyone who enjoys a pint of beer or a drink of Scotch whiskey. Most of the barley grown, however, is used not for malting, but for livestock. Because animals use six-sevenths of the original calories fed them to carry on their own life processes, it takes about 7,000 calories in feed to produce a chop or steak containing 1,000 calories. This means that between the plant, the primary consumer, and man, the third consumer, there is an 80 per cent energy loss in the common food chain—barley: cow: man. However, because steaks taste far better than oat cakes or boiled barley, conditions will have to worsen considerably before we human beings eschew the high quality proteins in meat in order to save the vegetable calories that animals waste. No matter how we use the barley and oat crops of the world, the fact remains that we do not want a virus pathogen to cheat us of the harvest.

The virus that appeared with startling suddenness in 1951 was named Barley Yellow Dwarf (BYD) because of its striking effect on the sick host. In 1951 the Pacific and Mountain states suffered a combined loss of approximately 10 per cent of their barley and oat crop from BYD, a loss amounting to many millions of bushels, five and a half millions in California alone. This was bad enough; but in 1959 BYD hopped over the mountains and caused damage estimated at 50 per cent of the oat crop, 30 per cent of the wheat, and 20 per cent of the barley in South Dakota. In the five states of Kansas, Iowa, Wisconsin, Indiana, and

Missouri, the losses in oat crops came to 74 million bushels; in Missouri the loss went as high as 37 per cent.

Moreover, Barley Yellow Dwarf has already spread to two other continents, Europe and Australia. Plant pathologists were not long in discovering that this new strain of virus was being spread with the help of countless aphids, also called plant lice. The pathologists' search was shortened by information obtained decades earlier: that these sucking insects and their allies, the leaf hoppers, helped to disperse all the virus diseases of potatoes, tobacco, and other plants by using their mouth parts as inoculating needles. Usually, these little bugs with long snouts are quite placid and sedentary. They sit by hour and by day with their proboscises deep in the sap-bearing cells of their host's stem tissue, sucking up the food-rich sap. Only when the host plants begin to wither after infestation by hundreds of these insects do the aphids sprout wings and drift on the winds to new fields, bearing the virus with them. Since the virus can live inside the aphids until the aphids feed again, any healthy host is doomed: the virus enters the new host in the aphids' saliva.

In 1951 countless numbers of aphids were in barley and oat fields. But, the plant pathologists reasoned, a virus cannot come out of nowhere. Someone thought of the perennial grasses of the Pacific Coast states, and a long series of painstaking experiments was started. The virus was subsequently found in those wild grasses, and so the reservoir of the disease was discovered.

The control was not so easy. It was impossible to find and weed out every diseased grass plant. To handle the problem the pathologists called in insect specialists, the entomologists, who suggested sprays; but the astronomical numbers of the plant lice that had spread over the vast acreage of young, juicy oat and barley plants made spraying impossible. Resistant varieties of oats and barley were not very valuable as high yielders of good quality grain. Nevertheless, the plant breeders began the long and arduous task of creating new resistant varieties. Even so, the greatest vigilance and the most painstaking agricultural research will be needed to keep Barley Yellow Dwarf and its little green helpers, the aphids, from causing a disastrous famine somewhere in this overcrowded world during the next quarter-century.

Let us suppose that a familiar fungus, bacterium, or virus suddenly turned viciously virulent—which can and does happen—and attacked, say, the legume crops of the world. Suppose that in its initial attack it destroyed two-thirds of the beans, peas, soya beans, peanuts, and the other edible seeded legumes. What would happen to man if the new disease struck next year, and thereafter took the same annual toll?

Man would lose at one stroke 10 per cent of his food supply, and a very valuable portion of his diet, for the legume seeds are rich in oils and proteins. If such a disease struck, the daily average caloric intake would drop by 240 calories, leaving the unfortunate two-thirds of mankind in the Far East on a subsistence diet of 1,800 calories, and dooming countless millions of them to slow starvation.

It is unlikely that any great catastrophe is going to take place in a technologically advanced country whose government maintains groups of scientists situated strategically throughout the country to work closely with local farmers, horticulturists, and the like. The work they are doing to increase crop yields is most encouraging indeed. In this regard a case can be cited to show what a high degree of co-operation between scientists and growers can achieve.

In 1940, Lulu Island, a low-lying diked island in the mouth of the Fraser River, British Columbia, was famous for the high quality of its seed potatoes. But slowly the economy of the island began to change from almost completely rural to semi-urban.

Thousands of people from the nearby city of Vancouver moved to Lulu Island because building lots were cheaper and land taxes were lower. They built homes and planted their gardens, including little plots of potatoes. As amateur potato growers, the islanders were careless about the quality of their seed potatoes, and they knew little or nothing about aphids or leaf roll. Consequently, their small potato plots served both as focal places of infection for the virus disease and as safe, unsprayed havens for the aphids. Moreover, encouraged by the success of the pioneer potato growers of the area, many other farmers turned to potato growing. By the late 1940's, Lulu Island was a mosaic of potato fields and little garden plots.

Meantime, across the Fraser River to the south, a sugar beet seed industry had been started, with hundreds of acres planted in this crop. Since the sugar beet is a biennial, it must be left in the fields over the winter in order to produce its seed the second year. The aphids found these fields an excellent place to spend the winter. In the spring, however, the aphids migrated by the thousands to the young potato plants of Lulu Island. The aphids reproduced so rapidly that by August they swarmed over the potato fields in countless billions.

The results were catastrophic. The leaf roll disease spread so widely that potato growers could no longer raise seed potatoes that could be certified by government inspectors. They could not grow potatoes even for local consumption because badly infected tubers showed internal brown markings, and the consumers refused to buy them. Consequently, many of the farmers were forced to sell their farms to housing promoters, and the trend from a farming to an urban community accelerated.

Not until the 1950's did Dr. N. S. Wright, head of plant pathology at the Canada Department of Agriculture Research Station at Vancouver, and a team of scientists begin to make real headway in their studies of this local plant disease. Hundreds of experiments were made, and by the 1960's Dr. Wright had the answer. The best way the few remaining potato farmers could deal with the problem was to "roll with the punch". The farmers should concentrate on early varieties and defoliate the potato plants about the first week in August, when the billions of vector insects, the green peach aphids, begin their infection flight.

The defoliating chemicals destroyed the leaves which were the "pastures" of the aphids, and without food the insects died. Of course, the potato plants died, too. But by the first week in August the early varieties had produced the bulk of their potential crop. Moreover, the potatoes were of such high quality that government inspectors could certify them for use not only as "seed", but also as foundation stock. Foundation stock is purchased by certified potato-seed growers in other potato growing areas of North America and brings a high price.

As a result, the farmers of Lulu Island can again profitably use their rich land for potato growing, and the lamentable trend of using agricultural land for urban purposes has been slowed in this area. In local situations throughout the world, this type of co-operation between agriculturists and scientists will probably be the most effective way to fight plant diseases and to increase the production of food.

Plagues and Paddy Fields

My beloved's rice,
Blue bowled and softly cradled,
Strengthens my ardour.

Strengthening the affection of a Japanese swain writing a *haiku* for his beloved is not the only benefit bestowed by rice. Rice provides the daily energy for at least one-third of the world's population. It is sown, weeded, and harvested by millions of farmers in millions of paddy fields that vary in size from a few acres on the great flood plains of the Asian rivers to patches so small a child can jump across on the terraced slopes of the rain-drenched eastern mountains. The countless handfuls, basketfuls, and tons of carefully harvested and gleaned paddy, as the unhusked rice is called, swells to a total annual crop of over three hundred million tons, from which two hundred and thirty million tons of rice are husked. Ninety per cent of this world rice crop is grown in the continent of Asia. Of the non-Asian countries, Latin America is the largest producer with nine million tons annually. Africa produces six million tons and the United States almost four million.

There are two main kinds of rice, the short and somewhat round grained *Japonica*, and the more common longer grained *Indica*. The longer grained rice is grown in the tropics, the *Japonica* in the northern latitudes, almost to 50 degrees above the equator. It has been grown profitably as far north as Czechoslovakia; and it flourishes in such extreme habitats as the valleys of the Himalaya Mountains and the tropical swamps of Africa.

Oryza sativa, the commonest rice, is second only to wheat as the most valuable grain species. *Oryza* is derived from the Persian word for rice, and *sativa* simply means planted. There are, however, about 25 other species and 7,000 varieties. Some of the species can be grown on dry land farms; but the heavy-yield *sativa* varieties need water—tons and tons of water per acre—to produce the best crops. Australian rice growers who use modern methods, including power implements and commercial fertilizer, have been able to produce one hundred bushels of paddy per acre. The South Asian farmer, who is lucky if he has one water buffalo for power and a little night soil to add to his paddy field, averages perhaps twenty-five bushels per acre.

The primitive but time-tried method of rice farming employed by most Asian farmers is to seed by broadcasting, transplant the seedling by hand, and then weed. Each step is backbreaking drudgery. North American growers engaged in commercial production of rice have successfully used aeroplanes for seeding and power machinery for spray weeding and harvesting.

The cultivated grain, standing two to five feet high and resembling oats in its mature stage, developed from wild grasses long before Stone Age man found it growing on muddy lake shores and deltas. In spite of the Persian origin of its name, rice was indigenous to the swamplands of Southeastern Asia, where its cultivation became widespread. The economy of the Asian peoples has been solidly based on rice culture for thousands of years; and rice has been such a staple food that its name in many eastern languages (Japanese being one) is synonymous with the word for meal. In fact, to most Asian people, if there is no rice there is nothing at all to eat. With so many millions of people absolutely dependent on a supply of rice for their basic subsistence, anything that affects that grain will in great measure affect the affairs of the world.

In eastern countries the horse likes rice, the water buffalo likes rice, and even the cats and dogs like rice. House partitions are made from rice paper. Rain hats and cloaks and even ropes can be fashioned from rice straw. In fact, the rice plant is almost as valuable to the Asian as the American bison was to the North American Plains Indian.

The paddy fields, irrigation ditches, and ponds have served a dual purpose since ancient times, providing fish to supplement the diet of the rice farmers. To successfully raise the golden carp and about ten other varieties of fish that are cultivated, the diked field or ditch must have enough water to keep the fish from being scalded by the tropical sun. The fish live on algae and fungi and other weeds that would be harmful to the grain's development. Moreover, they eat insects in and on the surface of the shallow ponds. Indeed, by cleaning the paddy water of anopheles mosquito larvae and pupae, fish do a great service in preventing malaria from becoming a bigger menace than it is.

The greatest benefit, however, comes when the fish are used to supplement the farmers' income and his diet of rice, rice, and more rice. In eastern Asia the annual fish crop from ponds and paddy fields exceeds about 500 million tons. Fish and soybeans help to replace the nutrients that are lost in the milling and polishing of rice.

The rice kernel when harvested is tightly enclosed in glumes, or chaff, that form the rough outer hull. Whether the hulling process is done by primitive grinding stones or by modern machinery with rollers, much of the nutritive value is lost. However, the primitive method of hulling did retain most of the brownish bran layer beneath the hull where some vitamins and minerals are concentrated. But, as with wheat and the other grains, the customer, as well as the farmer—who, incidentally, eats more than two-thirds of all the rice grown—began to demand cleaner and whiter grains. Today, therefore, practically all the hulled rice is put through a polishing process that removes almost the last traces of vitamins, proteins, and minerals, leaving a kernel about four-fifths starch.

A steady diet of polished rice, although rich in carbohydrates, is injurious to health. Since rice is deficient in amino acids, which combine to form proteins, it is a poor builder of body tissues. Outbreaks of beriberi have been very common among the people of Southeast Asia, farmers and city dwellers alike. Moreover, other insidious deficiencies in polished rice cause a drastic lowering of life expectancy among the people who depend upon it for their major food supply. No health campaigns to date have been successful in changing modern taste, and so flavour and nutrition are sacrificed for the kernel's white appearance. The densely populated countries have an urgent need to increase their caloric intake, as everyone knows. At the same time they have a vital need to increase their protein intake. Wheat and rice account for 41 per cent of the food used by the people of the world. Corn and potatoes account for 5 per cent. Therefore, if rice crops fail, the only readily acceptable substitute is wheat. But family custom and cultural traditions, plus individual tastes, pretty much determine what kinds of food will be eaten. (Not that only poor people in poor countries have poor diets, far too many well-to-do people in luxury nations that know better have diets that, ironically, are nutritively impoverished.)

The first mention of rice cultivation occurs in Chinese writings whose authors noted the privilege of growing paddy was reserved for the emperor himself. Less important court personages were presumably allowed to eat less important cereals. Hindu books record that offerings of rice were part of many religious rites. Three or four thousand years ago, Ceylon, judging from the extensive ruins of tanks and canals for rice culture, must have been the granary of the East. By 1000 B.C., the Chinese writers mentioned the growing of paddy so often that the grain is thought to have been commonly cultivated during the Middle Kingdom. The Japanese got it from China 2,000 years ago. There was, and still is, no other grain that is as constant in yield year after year as rice, or that produces such a solid base for an economy, especially in heavily populated areas.

Although Alexander the Great ate rice in India, the "pearly grain" did not come to western Asia or Europe until two or three hundred years before the Christian era. The Romans imported rice as a foodstuff from the paddy fields of Egypt, but methods of rice cultivation seem to have been unknown to Europeans until the Saracens and their allies, the Moors, introduced paddy culture into Spain. Rice growing was begun in Italy in the fifteenth century. It began in the New World when the Portuguese took it to Brazil. Although rice culture on the North American continent dates from 1718, the first commercial crops came as late as 1905 in Arkansas and 1912 in California.

As the world's population rises, a great increase in paddy culture is essential because rice is the grain that will give the highest average yields. Moreover, it is the only grain that can be grown in the same fields century after century without ruinously depleting the natural soil fertility.

Another favourable characteristic of this grain is its ability to grow almost anywhere if it is well irrigated. Paddy has been grown on every kind of soil, from the very richest to the very poorest, but one requirement is an impervious subsoil so the young plants can have their "feet" in the water. Irrigation, of course, is an absolute necessity for paddy, which means 40 to 60 inches of water per crop, and man's ingenuity has been well tested by the problems of getting this water to the fields. On the flat plains of the rice-producing countries, spring floods bring water. Temporary dams are built on small streams, and when they break under pressure or are breached by the farmer, the paddy fields are flooded. In drier lands, reservoirs must be built to catch rainwater. Millions of acres are still irrigated by man-powered sweeps that dip water from a river and are then swung and tipped to splash it into ditches. In other lands little paddle wheels to lift the water onto the land are spun by the feet of patient farmers, their children, or their wives. In the industrialized United States, powerful pumps supply water to the rice farmer for as little as $8.00 per acre, while in Israel spray irrigation is used.

This grain, flourishing in watery fields where other cereals would surely drown, seems tough enough to withstand any catastrophe of nature and still yield a fine harvest. Alas, the hardy rice has many enemies, from bobolinks and land crabs to the tiniest viruses and fungi. Each enemy, according to its kind—and its opportunity—marauds, grows and stunts, or blasts and sucks until the annual rice loss to all the pests approaches an ominous 20 per cent.

About forty parasitic diseases attack rice. Three of the worst are blast, brown spot, and foot rot.

Blast, or rotten neck, is caused chiefly by the fungus *Piricularia oryzae*. Bluish spots on the leaves and stem, spots that later turn brown, are the first symptoms. If the plant is attacked early, the grain never fills out; but if the disease comes later, the weight of the grain bends and then breaks the weakened stem of the panicle (head), and the grain falls into the pond or muddy ground and is lost. Mercury dusts and the old reliable, Bordeaux mixture, are said to help control this disease.

Brown spot often resembles leaf smut because the fungus frequently attacks kernel husks of the rice and turns them dark brown or black. No control measures have ever been effective against this ubiquitous disease. The burning of all straw and stubble after the harvest is necessary to minimize the danger of another and equally destructive attack in the following growing season.

The bakanae foot rot disease of rice, which is caused by the *Gibberella fujikuroi* fungus, has a most unusual result. The fungus during its development may produce, at the same time and in the same plant, both a root-stunting chemical and a growth-stimulating acid, called gibberellic acid. The infected rice seedling may first reach three times its normal height, then die. Experiments conducted with the acid show that even a weak solution sprayed on growing seedlings produces multiple effects. A bean plant treated with gibberellic acid will grow several feet taller than its untreated cousin, offering promise of a giant crop. Unfortunately, the plant is spindly, and man's dreams of a quick way to double, even triple, the production of food plants in the world collapse with the weak stems of the treated plants.

Virus diseases also take their toll. One of the most serious is rice stunt or rice dwarf, and it appeared first in Japan, where it caused widespread crop damage. It is an interesting disease to the plant pathologists mainly because it was the very first disease proved to be spread by sucking insects—actually two species of leafhoppers. The disease was first reported and studied in 1874 by an investigator who claimed—and proved—that the disease was caused by the bite of the leafhopper. Twenty years later, though, the final link was discovered: the role of the leafhopper was simply to carry the parasitic virus. The severe dwarfing of the rice plant from this disease continues to result in heavy loss of harvest.

Stripe disease is a virus spread by sucking insects. Fortunately for the rest of the world it is so far contained within Japan, although there is no assurance that this isolation will continue.

Hoja blanca, a very new virus disease was first found in the rice fields of Cuba and Venezuela. Recently it crossed the Caribbean and is now in Florida, probably carried in the alimentary tube of a guileless little leafhopper or aphid blown across the Gulf of Mexico by a hurricane. Crop losses to hoja blanca sometimes reach 60 per cent.

Each one of these three virus diseases is capable of inflicting very severe losses. More frightening to the hungry of the world, though, the description of each disease carries a final warning: no control known!

Of course it is still possible to reduce the numbers of aphids and leafhoppers by using the many insecticides available; but pathologists fear that eventually a leafhopper or an aphid strain will develop a resistance to the known chemical poisons. This alarm is not without substance. The leafhopper species now acting as vectors for rice stunt is so suited to the requirements of that virus that once a female leafhopper becomes infected, she stays infected. Every rice plant she feeds upon becomes infected in turn with the stunt disease pathogen. Not only does this adaptation complicate the work of the plant pathologists, but each young leafhopper that the female brings forth is similarly infected. This inherited chain of infection has been traced for seven generations. Such a persistent and widespread "pool" of the rice stunt virus generates severe and frequent outbreaks of the disease. If a new and more virulent strain of the virus appears, most of the rice growers of the world, who already exist on a marginal subsistence, will be in more dire trouble because they cannot afford expensive methods of control.

All the great rice-producing countries lie in that peculiar climatic area known as the monsoon region. In India the monsoons control the rainfall. From April to October, when air over the vast land mass of Asia becomes heated and rises, the wet southwest winds from the Indian Ocean, the summer monsoons, blow in over the land and bring torrential rains. From October to April, however, when the land mass has lost its heat, the northeast winds from the interior of the continent, the dry winter monsoons, drop down from the central plateaux and parch the earth.

During times when rains are light, there is little water for irrigation, and the rice crop is scant or fails completely. Sometimes the rains are so heavy that 480 inches of water has to be carried away by the great rivers. Then the Brahmaputra and all it tributaries rush down, level-banked and roaring with a mighty flood of water, onto the flat paddy plains of Bengal. If the floods come early, the seedling rice is washed away; if they come late, the harvest is ruined and hunger claims the land.

The people of the whole Western world, particularly the English-speaking world, have no firsthand knowledge of actual hunger. Most have never had the opportunity of speaking to anyone who has seen famine. Of course, here and there they have felt the effects of "hard times". Some have been so desperately poor that they sought governmental aid to get food. A few have begged for money to buy a meal. A few have survived the concentration camps and prisoner-of-war camps. But none have experienced the protracted, grinding, dehumanizing course of famine.

When huskings and peanut shells are ground for flour, and the dry soil is dug for grass roots, when the dust is winnowed for fallen grain, and worms and insect larvae are collected, famine is near. When children cry and retch, and the old and weak die, famine is on the land. As the time without food lengthens, the bodies of the sufferers—most of whom already have existed in chronic undernourishment—become slightly swollen with an accumulation of water that hides a wastage of muscles. Body processes fail. They lose appetite. Their memories become poor. Weakness and lethargy steal over them, and disease overcomes them. Those who are still living sell everything they possess in their desperate urgency to buy food. Money is borrowed against property at 100 per cent interest per annum. Only then, when all other relief has failed, does the peasant farmer dig up the little store of grain that he had kept buried, wrapped carefully, and dry, from the corner of his hut. Nothing but desperation will bring the farmer to sacrifice his future, the seed grain for the next year's crop, to his hunger.

Forty-eight major famines have occurred during the time that man has kept written records, twenty-three in India, most of the others in China. Even though the record for India is incomplete, one authority lists seventy famines, large and small, in the nineteen centuries from A.D. 33 to the present, the worst in over twenty years occurring as recently as 1966. Since 100 B.C. China's total is more than eighteen hundred. Some famines, of course, have been local, affecting small numbers of people; others, with the help of plague, that inevitable companion that always preys upon hunger-weakened people, have depopulated areas as large as Western Europe.

While floods and droughts and swarms of insects have been the grossly apparent agents of most Asian famines, the insidious fungi, the bacteria, and the viruses—much too small to be seen clearly, if at all—went unnoticed and unrecorded until recent years. Even now the damage from diseases caused by these pathogens, although widespread, is often overlooked or considered unimportant in some rice-producing countries. Yet with favourable weather conditions, any of the rice diseases might become epidemic. In 1934 and 1941 Japan suffered famine in some areas from an epidemic of rice blast, and the major factor in the devastating Bengal famine of 1942–3 that killed a million people was the brown spot disease.

Besides natural calamities a potential cause of famine may be the radical disruption of environment by scientific warfare. Aside from the moral questions that have been raised during the decade and more of the Vietnam civil war, large-scale ecological disturbances have occurred in this densely populated area. The bomb-broken bunds (dikes) between the paddy fields have caused erosion of the rich soil, and the defoliants have injured cultivated plants. The deaths of Vietnamese farmers and the destruction of their fields have been responsible for a serious loss of rice production in the Mekong Delta and in the north. Surviving farmers and their families, frightened away from combat zones, will have to build new rice fields—a long and unproductive process. Consequently, a serious reduction in the quantity of rice grown will exist for many years in that land. Large amounts of basic foods will need to be imported for an undetermined period.

Farther north, Red China has bought hundreds of millions of bushels of grain from the exporting countries of the world, an indication that their paddy fields are not producing rice in needed quantities. The imported grain is used to supplement the food of workers as well as to bring high-grade seed grain to the agricultural communes.

All over Southeast Asia, however, at best only 220 pounds of rice per person per year is available. Recently in India, after two seasons of partial drought, a great many lives were saved from the threat of famine by massive shipments of wheat from the Western world. As a further aid to India in her efforts to stave off a serious famine, the United States promised to sell that country one-fifth of the American 1967 wheat crop.

Thus famine springs from many causes, some political, such as the breakdown of governments, wars, or excessive taxation. Some are economic—exportation of needed foodstuffs, lack of low interest funds to tide farmers over unfavourable periods, inefficient transportation, lack of communications. Although most famines have resulted from crop failures due to drought, some have certainly been caused by plant disease.

The Food and Agriculture Organization of the United Nations, under the directorship of Dr. Binay Ranjan Sen, invited the rice-growing countries of the world to take part in the International Rice year, 1966. The purpose of the ambitious and wholly essential project was to encourage the paddy farmers to use new, more efficient means to increase yields. To this end, information and aid is being supplied.

One objective of the FAO directorate is the production of more inorganic fetilizers. Needed simultaneously is the education of the paddy grower in their use. It takes a good deal of straight talk and earnest persuasion, in addition to positive evidence, to convince a poor farmer of east Asia that the grey, strange-smelling dust in the fertilizer bag will, if sprinkled over his fields, give him and his family unheard of increases in his rice crop.

Another very promising, spectacular, but expensive method for increasing yields is to remove two or three feet of topsoil and then lay an impervious blanket of asphalt over the subsoil. When the topsoil is replaced the field can be flooded more easily because the asphalt prevents irrigation water from seeping and escaping into the earth. This guarantees that the plants' "feet" are always wet. Yields have been increased 50 to 100 per cent by this method, but it is difficult to foresee how the millions of peasant farmers of Asia could bear the expense.

The world's rice crop can be increased by making more water available for irrigation. Already wells have been drilled by the thousands to tap the pools of sweet water far below the parched fields. Great dams have been and are being built on the rivers in Pakistan, India, and China, three countries of intense population pressure.

A new short-stemmed rice that matures in 120 days and that can use nitrogen fertilizers more efficiently has yielded an amazing 150 bushels per acre. At least two crops of this fast-growing rice can be reaped per year. This phenomenal yield is a heartening contrast to the present Indian average of 25 bushels per acre.

New programmes of education have also been started for the prevention of loss by rots and moulds during the storage period. At the present time, farmers in some countries simply pile the rice on the ground until it is used. Fungi and bacteria, aided by insects and rodents, often cause a loss of 30 per cent before the paddy is even husked. Then, of course, crude milling methods crack and ruin another 10 per cent of the harvest. One country, Burma, which asked the FAO for help a few years ago, now has modern storage facilities for three million tons of rice.

Even with the best efforts of the FAO and its hardworking experts, rice production is increasing only 1.4 per cent each year. Asia's population is increasing at 2.5 per cent. How will this problem—the world's most serious one—be solved?

Engineers must build dams to control and conserve the waters of rivers. They must also build irrigation canals to the rice fields. Agriculturists must prepare the soil by using balanced fertilizers and proper tillage. Geneticists must provide the best rice seed, and entomologists must train farmers to guard against and fight off insect predators. Finally, and probably most important, plant pathologists must teach the rice growers to recognize plant diseases and to use methods of control, whether the disease is one that affects a standing crop or one that rots improperly stored grain. Otherwise, the gaunt spectre of famine will assuredly harvest a human crop.

10 Tall Stood the Forest

SOME TREE DISEASES

When the lazy, hazy days of autumn come and a blue veil lies across the far-off hills, everyone enjoys the softness in the air—everyone but the forester. That haze means smoke, and smoke means trouble in the forest, for the blue smoke that drifts eastward across North America means fire is eating into the dry forests of the continent.

Although fire is by far the most dramatic foe of great forests, it actually accounts for only 17 per cent of the total annual destruction. Two other enemies account for an even greater loss. Insects, countless in number and ranked in thousands of species, suck, chew, and bore into the soft leaves, the corky bark, and through the sapwood to the heartwood of the trees. Such insects as the tent caterpillar defoliate. Others, such as the elm bark beetle, breach the protective layers of the bark, tap the rich food storage tissues, and bore tunnels into the wood itself. Altogether, these pests are directly responsible for 20 per cent of the losses to man's forest resources.

Far ahead of fire and insects, however, comes the greatest but the quietest and most inconspicuous of the timber destroyers: the fungi and the bacteria. Sometimes they invade the tissues of weakened trees to finish them off, but more often they initiate many serious or killing diseases.

Fungi sometimes enter the tree through its natural openings, the stomata of the leaves and the lenticels of the young and tender stems. At other times they get in through insect borings, fire cracked bark, or through the many other wounds that come to a tree in the centuries of its life.

Every Boy Scout, or bigger "boy", who goes whistling through the woods marking his trail by hatchet strokes will leave as many ports of entry for the fungi spores as the number of blazes he cuts. The birds of the forest, squirrels, rabbits, and deer also peck, scratch, nibble, and bite through the protecting epidermis of the young trees or of the new branches. The spores settle into the resulting wounds and the fungi squeeze their hyphae through the remaining bark and into the sapwood cells, spreading up and down the long, cavities of these wood cells and into the heartwood, weakening and killing the sturdiest trees, rotting the hardest wood. On the North American continent, forest losses to the fungi amount to over 20 thousand million board feet each year, or 45 per cent of the total loss, which is far more than the injury done by both fire and insects combined.

To minimize the disastrous damage to the forests and to fill the growing demand for a larger harvest from timberland, every country has established a division of forestry either within the central government or in association with it. Each state in the United States and every provincial government in Canada also maintains a forestry department.

This vigilance has a history dating back hundreds of years, at least in the Old World, where foresters were appointed to manage timberlands. Their duties were to supervise the cutting, thinning, and planting of the woodlands as well as to fight fire.

Naturally, every forester on his rounds saw the frost damage, lightning slashes, wind breaks, and other injuries to the trees. But conky logs, hollowed stems, and trees dying from mysterious diseases passed unnoticed—overlooked because of their commonness. These losses were looked upon as "acts of God" that man could do nothing about. They were disregarded.

About a hundred years ago in Germany, Robert Hartig, the son and grandson of foresters, joined his father in the forest service. But he returned to university studies, and in 1867 received his doctor's degree in botany. From that time until his death, Hartig served as a teacher and researcher in both botany and pathology. He instituted the study of tree diseases and published many papers and books on that subject. He studied a host of diseases affecting many kinds of trees, from the oaks to the conifers. Hartig was a very careful worker, and even now, almost a century later, his many projects in research are regarded as classics in the field of forest pathology.

Although Hartig was concerned mainly with studying the life history of each fungus pathogen, and did little or nothing in the study of the control of these diseases, he is acknowledged by all as the "father of forest pathology".

The American chestnut, *Castanea dentata*, was a magnificent tree that often reached a height of 100 feet or more and had a trunk diameter of up to four feet. The forest in which it was most abundant stretched from Maine on the east to Michigan and ran away to the southwest for a thousand miles, from the Great Lakes to Louisiana. In this forest, covering most of the eastern half of the United States, the chestnuts made up a full quarter of all the trees. In it the squirrels, the deer, the wild turkeys, and the little boys lived, played, and feasted on the delicious nuts that fell to the ground each Indian summer. Spring after spring came, and the great trees put forth their coats of green. When the chestnuts flowered, the forest, when viewed from the heights of the Appalachians, was a great sea with long whitecaps of blossoms cresting the dark billowing green. When fall came, the nuts grew large and sweet. This forest flourished for centuries, through the colonization of America, through the struggle for independence, through the hell of the Civil War, up until the dawn of the twentieth century. Then one summer a new malady suddenly came to that forest, and the splendid chestnuts began to wilt and die.

What was happening to the chestnuts?

This was what Herman Merkel wondered, in 1904, as he watched the magnificent trees in the New York Zoological Park sicken and die. As chief forester of the park he took immediate action. He sprayed the sick trees and made his report to the Department of Agriculture in Washington. The forest pathologists came to see the wilting chestnuts, and went away shaking their heads. There was no doubt that it was some new disease, a virulent one. But as yet there was no alarm. The sickness afflicting the chestnuts seemed to be confined to the park. The pathologists decided that Mr. Merkel would just have to remove the dead trees and replant. There were millions of vigorous young chestnuts from which to choose replacements, and in twenty years this stand of trees would be as fine as the old one.

Unfortunately, the trouble did not end in the New York Zoological Park. The following year ominous reports were received by the Forestry Division of the Department of Agriculture in Washington. The disease had broken out of the park, and chestnuts were dying throughout New York State. Everyone concerned was alarmed now, but no one knew what to do. Finally, in 1907, the Department of Agriculture set up a special laboratory to study tree diseases, and chestnut blight headed the list. Although plant pathologists gave it their most earnest attention, the blight continued to spread its grey tentacles. Dendrologists, the people who study trees and forests, and government leaders at various levels acted swiftly and wisely in an attempt to stop the new blight's slow advance through the eastern forests. Pennsylvania, for example, placed more than half a million dollars at the disposal of its Chestnut Blight Commission to fight the disease. Nearby states launched similar control programmes. The researchers who were hired with government funds began experiments and soon got positive results.

Early in their investigations the culprit was uncovered. It was a fungus, *Endothia parasitica*, a killer that lived and spread in perfect safety under the protective bark of its unfortunate host, the chestnut tree.

Bark, contrary to popular opinion, is not merely a corky protective covering. It also contains two other vital tissues. The innermost layer, phloem, functions in food circulation. The layer between the phloem and the cork is made up of the cortex cells and is the chief food storage tissue of the tree. Phloem is composed of millions of tiny, thin-walled tubes that transport all the foods—sugars, proteins, and fats—that are manufactured in the leaves. This life stream of dissolved foods is carried upwards to the twigs and the developing fruits and downwards to the roots. Surplus foods manufactured in the leaves during spring and summer are stored in the cortex.

The chestnut blight fungus invades these vital phloem and cortex tissues. Its mycelium, the matted threads of the body of the fungus, spreads in a feltlike mass thrusting its countless hyphae into the cortex cells to tap the rich food bank stored there. Other hyphae penetrate deeper into the phloem where the sugar-laden sap runs. The blight fungus then grows in circular cankers that kill the cortex cells and plug the tubes of the phloem. The cankers eventually girdle the twigs or branches, and all of the parts located beyond the infection wilt and die. The disease jumps from twig to twig, from branch to branch, and when the cankers girdle the trunk the whole tree dies.

If the canker is not disturbed, the fungus feeds, strengthens, and thrusts hundreds of fruiting bodies outwards through the bark. The fruiting bodies show as tiny yellow or orange pustules about the size of pinheads. If the weather is damp enough, long, twisted threads called spore-horns force their way outwards through the fruiting pustules; then each spore-horn, actually a long thread of millions of sticky spores—pycnospores—is washed away and becomes disseminated by raindrops or is spread through the forest on the feet of insects, birds, and squirrels.

As if the billions of spores produced in this way were not sufficient for efficient reproduction, the chestnut blight that struck North America had another, more effective method of spreading. After producing spore-horns, the fruiting pustules changed character and formed millions of asci or little sacs. Every sac contained eight ascospores. When each ascus, pushing up through bottle-necked channels in the fruiting pustule, reached the surface, it exploded and shot its load of eight spores into the air. Thus, aided by the shifting winds, this fungus blanketed the great chestnut forest of the United States with its deadly inoculum.

Why, then, when the fungus fruiting bodies on one diseased tree produced billions of spores, did the blight take upwards of forty years to wipe out the American chestnut?

The forest pathologists did not take long to find the answer. Chestnut blight could enter the bark only through a wound. However, the tiniest scratch in the bark was enough to allow the entry of the strangling fungus. Even the squirrels that scurried up and down the young branches, making millions of tiny scratches, were a menace to the very trees that gave them their food.

The real allies of the chestnut blight were soon found to be not squirrels but boring insects that lay their eggs in the bark. Even with this knowledge, plant pathologists found themselves helpless. The fungus was too virulent, and there were too many insects.

Every attempt at control failed. Every promising idea of the trained workers proved ineffective in practice. The chestnut blight spread south and east, wiping out the forest as it went or as it skip-jumped from one chestnut stand to the next, scores of miles away. By 1915, all the government agencies concerned had discontinued their programmes, and the chestnuts were abandoned to their fate.

Cats are said to have nine lives. Some of the chestnut trees had as many, or more. Every time the blight killed parts above ground, the w/

roots sent up new sprouts. Even now there are still a few chestnuts struggling for life. A miracle could still happen. In some obscure forest nook, a change, a mutation, might take place in the cells of a single chestnut sprout that would make that sapling resistant to the blight. If the scientists could find just one such mutant, it would be possible to propagate this sprout by cuttings, and the chestnut would stage a comeback. However, no such resistant sprout has been found yet. And if one such mutant were ever to appear, it would be a long time at best before chestnuts could be re-established in the American forests. At present, other trees have crowded in to take the space they once occupied, and these would have to be removed to leave room for replanting.

The Chinese chestnut is a smaller tree and less desirable than the native American variety for timber and nuts. However, crossing these two species seems to offer the only real hope, since at least the Asian chestnuts are highly resistant to the blight fungus. Much of this work of hybridizing is being done by Dr. A. H. Graves on Sleeping Giant Mountain, Connecticut. Many of the hybrid chestnuts are fifty feet high, clean of disease, and some of them bear nuts that are full and sweet.

In attempts at creating successful hybrids, the greatest obstacle is the fact that the offspring of the two different species are almost always sterile. This sterility of the hybrid has prevented man from creating new animal species. But the problem of sterility in plant crosses can sometimes be overcome by the judicious use of certain chemicals. The action of colchicine, for example, by doubling the chromosomes in each cell, makes possible the fertility of the hybrid plant. There are many dendrologists skilled in experimental techniques and in genetics, so it is quite possible that a fertile tetraploid chestnut seedling—one having four sets of chromosomes per cell instead of two—might yet be developed and prove to be resistant.

The loss in lumber on the 33,000,000 acres of Appalachian forests, where chestnuts once made up 25 per cent of the stand, has been assessed at about 30 thousand million board feet. Chestnut lumber was second only to oak in usefulness and durability. Its wood was as beautifully grained as the oak and was used for interior house joinery, furniture, and flooring. Moreover, its great durability and its resistance to weathering and dry rot made chestnut a fine work-a-day wood, and it was used for poles, railway ties, outside lumber, and coffins.

Not quite all the wealth of the chestnut forests was lost because of the superb durability of chestnut wood. Dead trees salvaged within five years provided lumber in good condition, but the loss was reduced by only a small percentage.

The chestnut tree provided the American people with still another source of wealth. Stored deep in the wood cells lay a rich deposit of a valuable chemical, tannic acid, which is used in the making of leather. The heartwood, which made up the bulk of the tree, often contained anywhere from 7 to 12 per cent tannin.

The industry for the extraction of tannin from the chestnut trees was concentrated in the great forests of the Appalachian region where several large extracting plants had been built. With the death of the chestnuts this industry collapsed and American leather makers were forced to obtain tannic acid elsewhere.

What was the price that the chestnut blight extracted from the American people? A thousand million dollars would be a very conservative estimate of the primary loss. Moreover, animals of the woods lost their chief source of food supply. Squirrels and deer were decimated, and the great flocks of wild turkeys disappeared.

But that was not all. Somehow the fungus, having destroyed "the spreading chestnut tree" in North America, was carried across the Atlantic in the 1930's, finding a suitable host in the European species of chestnut which made up about 15 per cent of the forests of Italy and other southern European countries.

✓Strenuous methods adopted to control the blight in Italy contained the disease during the thirties; but when Mussolini led his people into World War II, the fight against the fungus was forgotten and the blight silently devastated the Italian chestnut forests. Within fifteen years Italy lost most of her source of chestnut lumber, and today the diminished nut harvest is too valuable to be used as hog food. Some of these chestnuts are used to supplement the Italian diet and the rest are exported. The United States and Canada buy about 2,500 tons of chestnuts from Italy each year but, as the disease creeps through the Italian chestnut stands, the supply will dwindle.

The only large chestnut forests extant in the world today are in China. As long as this Chinese species remains highly resistant to the blight fungus, little boys will be able to compete with the squirrels for these delectable nuts, but likely not in North America.

Dutch Elm Dis

Although the American elm is not as valuable a tree as the chestnut, it is a large tree, often reaching a height of 100 feet or more, and the lumber it produces does have some remarkable qualities. Elm has never been prized as a building material, but it is a tough wood with great bending qualities and ability to hold screws. It has been most widely used in the manufacture of the wooden parts of automobile frames and farm implements.

In the early days, English elms, a species different from the American elm, were introduced into America. They were planted along the streets and avenues of many Canadian and American cities and towns. Their spreading crowns met high above the street to form a canopy that shielded the traveller from the summer sun. These elms became the pride and joy of the urban dweller from the Atlantic Coast to the Mississippi, and from Lake Superior to Mexico.

In the summer of 1930, the first sick elms were discovered almost simultaneously by two scientists in Cleveland and Cincinnati. One of the scientists, Christine Buisman, was a plant pathologist from Holland. She was shocked by what she saw in the dying elms: in and under the bark were spores and hyphae of the dreaded Dutch elm disease fungus that had already denuded the streets in her own country.

This fungus had first appeared in Holland in 1919 and had spread through Europe. In 1927 it had crossed the English Channel and begun its attack on the elms of England. Now it had crossed the Atlantic.

A little sleuthing gave federal scientists the answer to its sudden appearance in the United States. Some furniture manufacturers had been importing burled elm logs from Europe to make a beautiful veneer for cabinets and tables. The hardy spores of the Dutch elm disease had come across the Atlantic in the bark of the imported elm logs.

The forest pathologists, of course, realized what would happen if the disease was not checked. They knew that if the elms died the disease might cost the American taxpayers far more than the great market crash of 1929, when the paper wealth of the nation had declined by millions of dollars.

The fears of the pathologists were well-founded. The Dutch elm fungus had found old friends and allies in this new land. These allies had come to America years before but had found the going hard. They were hairy little monsters that rode the wind. Entomologists who knew the insects as European elm bark beetles had been alarmed when they first spotted them in America. However, the European beetles' depredations had been limited, and soon they had been classified as just another pest, like the native American elm beetle. The American elms, scientists had agreed, were well able to resist the nibbling and boring of these two insect nuisances. To thrive properly, the European bark beetles had to find dead elms, or at least dead branches, under whose bark their larvae could develop. The American elm was a remarkably healthy tree—or it was until the Dutch elm disease invaded the country. Then, that fateful summer of 1930, the two species, the deadly fungus and the elm bark beetle, came together again in a continent where a thousand million elms grew in all their lofty beauty.

The Dutch elm disease fungus, like the chestnut blight fungus, must find a wound in the bark, and almost invariably the wounds in the bark of the elms were made by the two bark-boring insects that now infest the remaining elms of North America. The beetles chew into the bark for the juicy sap that flows in the phloem tubes. The fungus spores, carried on the hairy legs of these insects, get into the wound, where they germinate and penetrate through the bark right into the sapwood. Once in the wood cells, the fungus buds and rebuds like yeast until there are millions of spores that swarm in the tiny xylem tubes carrying water and mineral salts to the leaves. The toxin these spores release soon shocks the tree into plugging the xylem cells. The upper branches and leaves wilt and die upon being shut off from soil, water, and nutrients. The disease proceeds so rapidly that young and vigorous elms often succumb within two weeks.

Parasites that kill their hosts are counted to be exceedingly clumsy. Once the host is dead, of course, the parasite itself is bound to die. However, the Dutch elm disease fungus is not a clumsy parasite. The fungus simply changes its role after the elms die, and it becomes a saprophyte—a plant that lives on dead organic matter. It digests the dead tissues of its erstwhile host and works outwards from the sapwood to the bark, where it rejoins the descendants of its ally, the bark beetle. The beetles laid their eggs when the elm died; and about the time the pupae of the beetles stir in their myriad nests under the dead bark and emerge as young beetles, the fungus reproduces and covers their hairy little bodies with countless spores. Then the beetles spread their wings and go looking for juicy elm twigs to satisfy their hunger. The spores fly with them, and when the fungus finally kills the next elm, its dead bark makes a shelter for the next brood of beetles.

In 1930 there were an estimated one thousand million elms scattered through the northern forests that lay in the shape of a great flat crescent ranging from the Atlantic Ocean along the St. Lawrence watershed and around the Great Lakes from Maine to Minnesota. To the thousand million "wild" elms add another 500 million elms, those spared by pioneer axemen and left on farmlands, those planted deliberately along country roads, on farmsteads, and lining the streets of the towns and cities of Canada and the United States, and the magnitude of loss comes into focus. About half of the tame elms are already dead.

The cost to remove a dead elm and burn it down to the last twig, for that is the only way to keep the fungus in check, is at least fifty dollars. The total cost to date has been about twelve thousand million dollars, and replanting has cost municipal governments about three thousand million dollars more.

During World War II and the Korean War a minimum effort was made to protect the elms. Since 1953, however, the control programme has intensified as municipalities have learned that it is far cheaper to look after their elms than to replace them. Spraying with insecticides to hamper the bark beetles and to keep the remaining elms reasonably healthy costs about one dollar per tree per year—250 million dollars annually.

But the elms seem doomed, all of them, the wild and the tame. To fight the disease in the northern forests is a hopeless task, and even with the best of care, large numbers of the tame elms die every year. It is true that new systemic poisons—introduced as pellets into the bark of healthy elms—help to poison the deadly elm beetles and so check the spread of this disease. Even so, it seems to be only a matter of time until all the elms of North America are destroyed. The total cost? Fifty thousand million dollars!

Oak Wilt

Jove's tree,
Favourite of Thor,
Host of the mystic druid mistletoe!

In cool glades
Of ancient Samos
Blind Homer sang his lyrics 'neath its shade.

Its fruit,
The hooded acorns,
In pasturage lay to feed the Saxon porcine herd.

And sweetened
By the touch of fire,
Made rich black bread to fight off hunger pangs.

In Man's hand
It plowed and sheltered
And formed the shrouding cradle for his dust.

As peasant door
And castle gate
Kept out the rams of foemen and the beasts of night.

Beam and plank,
Strength before steel,
Let man sail onward through the ocean's rage.

Sweet wood,
Fragrant and gentle,
It's soothing casks change coarsest draughts to nectar.

God's gift
To groping man
From time primeval until now—the noble oak!

And man, not unmindful of the goodness of nature, has treasured the oak tree for a period that stretches far back before the era of written history. In his struggle to whatever state of civilization now exists, man has probably derived more benefit from the oak than from any other living thing. In the temperate zone the fruit of the oak was one of man's first vegetable foods. Of course, he had the chestnuts, the beech nuts, and the hazel nuts, but the oaks of the world were at least four times more numerous than all the other nut trees combined.

Members of the four hundred species of oaks are scattered through the forests of the world, but the greatest number are to be found in the temperate regions of Eurasia and North America. In North America the oaks are concentrated in the eastern half of the United States, where they make up one-third of the hardwood forests. The mixed oak-hickory forest extends in a five-hundred-mile-wide band from Minnesota to the Gulf of Mexico. To the south and east of the oak-hickory belt, the oak-pine forest curves from the Carolinas around the southern end of the Mississippi River. In the Far West a narrow strip of oak forest stretches from Oregon into California. Altogether, about twelve thousand million oak trees of thirty-five species contribute to the forest wealth of the United States. But the oaks are dying!

In 1944, the concern of foresters, pathologists, and various government agencies shifted from the chestnut and the elm: a new and deadly disease—oak wilt—had come to North America. First detected in the Wisconsin forests, the disease has spread at a slow rate, very slow, about six inches per minute. But multiply six inches by minutes and then by days, and we get the more meaningful figure of fifty miles per year. In seventeen years this disease has extended its centres of contagion along a great circular front to the farthest reaches of the hardwood forests of the eastern United States.

The circle of infestation is a flattened one to the north, because the colder climate of Canada and the north central states seems to form an impenetrable climatic barrier which the pathogenic oak wilt fungus cannot breach. To the south and east, however, the fungus finds no natural barrier. It has moved slowly across the land deep into the rich oak stands of Tennessee and South Carolina. To the southwest its slow creep has invaded the Ozarks of southern Missouri and Arkansas.

Actually, the disease does not "creep" into new forests; it somehow rides the winds over miles of healthy oaks to infect a single tree, then works outwards in a small circle. Such patches of dead and dying oaks are called infection centres by aerial survey crews that fly over the forests for the United States Department of Agriculture. The dead patches mottle the healthy green of the forest canopy like pustules festering in the skin of human beings stricken with smallpox.

Oak wilt is caused by another wound fungus, a relative of the Dutch elm disease. It gains entry into a healthy tree through punctures in the bark. Again, as in chestnut blight and Dutch elm disease, the ally of the fungus is probably an insect. The culprit seems to be the small oak bark beetle that feeds in the crotches of the oak twigs and around the bases of the leaves. At any rate, these beetles breed by the millions in dead outer sapwood of trees killed by the wilt and in slashes left after storms or careless logging operations.

The oak wilt fungus is a sac fungus that, like its relatives, produces spores in countless billions. Are these spores disseminated by the wind? Or are insects the main vectors of the oak wilt? No one is sure of the answer. The forest pathologists are still searching patiently and diligently.

Millions of dollars have been spent in control measures and techniques, surveys, and experimentations. It has been found that once a spore enters the bark through a wound and germinates, its mycelium probes deeply into the cortex and phloem of the bark and onwards into the sapwood. There it proliferates rapidly, and its presence irritates the tree so much that gummy deposits are laid down in the sapwood to try to block the progress of the fungus. Thus the tree chokes its own circulation system, and all the parts beyond that point wither and die. Despite all the efforts of the oak to resist, the fungus slowly spreads and inevitably kills the whole tree.

But the fungus does not die. It grows and creeps through the dead tissue down to the roots. Often, by way of natural root grafts, it passes from the dead tree to a new, living host.

In the dead oak the fungus forms fruiting bodies in and under the bark. When the spores are ripe, they are ejected into the air through insect borings or are carried out on the bodies of the young insects. Spirited away on the summer winds, the spores find another wounded oak and start the life cycle of the fungus again in a new centre of infection.

The few control methods that have been worked out for this dangerous disease are simple but expensive. Aerial and ground survey crews work co-operatively, the first to detect and the second to deal with the infection centres. Each aerial team, using a light plane or helicopter, consists of at least two men. They survey the forest in half-mile strips, pinpointing on a survey map any patches of dead or dying oaks. This map is then checked to determine if the infection centre is a new one.

When a new infection centre is spotted, ground crews are sent in. The dead and dying trees, as well as the healthy ones around the fringe of the area, are cut down. Even the roots of these trees are killed by applying a chemical to the stumps and, wherever possible, a trench is run around the area to sever all existing root grafts. The ground crews leave a patch of total destruction in the forests, killing about twice as many healthy oaks as the disease has already destroyed. Every possible effort is used to fight the oak wilt fungus.

Even when properly carried out, the measures outlined above are merely attempts to check the spread of the disease. Aerial surveys are quite expensive and are often disappointing to the foresters because, unless the infection centre is well defined, it escapes detection. Moreover, sick oaks of the white and chestnut species cannot be seen from the air at all. Surveys are consequently locating only about one-third of the diseased trees. Then, too, many local governments do not wish to pay for the expense involved in the costly ground crew work, and in those counties oak wilt is spreading with frightening rapidity.

The great alarm felt in the late forties has been allayed somewhat by the realization that oak wilt is not an epidemic type of disease that will totally destroy the oaks in a generation or two. However, even though the disease is endemic, it is virulent and will eventually decimate the oak forests of North America unless its slow march can be stopped. The immediate question is, what does the future hold for the oaks?

Reluctantly, scientists are forced to use such words as "if", "may", "might", and "perhaps". If the fungus can find a more effective insect ally, disaster will come quickly. But it may be that a new chemical spray will be discovered in time. Man might find a resistant species, or even produce a hardy mutation (though there is not a ray of hope so far in this direction). Perhaps man can find another tree with all the fine qualities of the oak. This is the wildest dream yet!

And what will be the total cost? We can only guess. The oak forests of America represent over one billion feet of lumber. At the ridiculously low price of thirty dollars per thousand, this amounts to thirty thousand million dollars. But no one can say how much will be harvested and how much will be lost to oak wilt. All we know is that each year the disease is destroying an increasing number of trees and that the United States stands to lose a big percentage of its oak forests, in addition to the millions of dollars spent each year in fighting the fungus.

The chestnuts are finished. Out of an estimated thousand million trees there were about 180 left in all North America in 1963.

The elms of this continent are going. Pathologists hold no hope. The only break in the clouds concerns two foreign species, the Buisman elm from Holland and the Siberian elm from the U.S.S.R., that are resistant to the Dutch elm disease. These elms are being planted widely as shade trees.

The oak trees have a brighter future. Oak wilt is scattered widely, but the percentage of infected trees is still low. In Wisconsin, the heart of the blighted area, at the present rate of destruction the disease will take an estimated three generations to wipe out the oak forests. Within this period, given adequate support, plant pathologists might be able to find new and more effective methods of control. On the other hand the fungus might develop a mutation with much more virulence and finish off the oaks in a single decade. If this happens, the toll taken by these three tree diseases will be a thousand million chestnuts, a thousand million elms, and twelve thousand million oaks. At one hundred trees per acre this would represent a forest equal to the land area of France!

No revolutions, no mass migrations, no famines have resulted from the death of the chestnuts, the doom of the elms, nor the danger to the oaks. But for millions of people the loss of these great trees has brought heartbreak, dislocation of industry, and financial ruin. Viewing a street of old houses under a merciless summer sun, one cannot but recall the days when shadows of magnificent trees dappled lawns and tempered the heat—days before the subtlest loss of all, the loss of beauty.

Epilogue

FOOD CRISIS

According to agronomists, food production could keep up with predicted population growth for decades to come if enough water were made available. One recently proposed project, the North American Water and Power Alliance Plan, envisages reversing the flow of water now going to the Arctic Ocean by way of the Mackenzie River in Canada. A system of dams, canals, and power plants would be constructed at an estimated cost of 100 thousand million dollars, and the Rocky Mountain trench in northern British Columbia would provide a natural reservoir as large as Lake Erie. The diverted water would flow as far south as northern Mexico and as far east as the Atlantic Coast. Millions of acres of land would be irrigated, and the Great Lakes would be brought back to their original level. This project would require the co-operation of seven provinces of Canada, thirty-five states of the United States, and three states of Mexico, as well as the central governments of those countries. It would also take many years to work out the necessary treaty arrangements and many, many more years to complete the project.

Although this project is said to be based on sound principles of engineering and economics and is described as capable of paying for itself in fifty years, the statistics given by its promoters are only estimates. The necessary treaty arrangements already negotiated between Canada and the United States for a project that will dam the Columbia River in the province of British Columbia took over a decade, and the cost is going to be several million dollars more than the original estimate. Thus the history of the Columbia River project does not promise early realization of the proposed Mackenzie River plan, especially since Canadians, unsure of their own future needs, are going to take a long, hard look at a proposal to divert across international boundaries a vital national resource in such great volume. But co-operation may be forced upon Canada, the United States, and Mexico and their political subdivisions by a common enemy—hunger.

Here history gives very little encouragement. In millions of acres now desert, the soil contains enough nutrients to grow crops; but all the water carried to the sea by all the rivers of the earth would irrigate only two and a half million square miles—an area not even as large as the Sahara—with the necessary fifty inches of water per year. Moreover, without proper drainage, irrigation only turns the land into infertile alkali flats like some parts of the Indus valley plain in Pakistan. Even were these problems solved somehow, nationalism is still too firmly entrenched among some peoples to permit the kind of international co-operation so far effected in North America. As recently as 1964, for example, the Arabs threatened to prevent Israel, by war if need be, from using Jordan River water to irrigate the Negev Desert. Such enmity is not likely to diminish if the question should ever become one of survival.

Some people think that millions of acres of tropical land now covered with jungle can be cleared to grow food crops. This is not true. Most of the soil of the wet tropics is laterite that has been leached until only insoluble compounds, mostly aluminium and iron, are left. These red or yellow soils, exposed to air and sun, bake into bricklike lumps and sheets and become about as fertile and suitable for farming as a paved road. Recently the Brazilian government spent a large amount of money to set up a colony at Iata in the Amazon valley. After five years of hard labour, the settlers were forced to leave. The equatorial sun had baked the soil solid.

Until now, Canadians and residents of the United States have tended to be complacent about the bruited world shortage of food and space and resources. With grain elevators and warehouses stuffed to their roofs, with farmers' granaries bulging with wheat, oats, and barley, and with millions of pounds of butter in cold storage, it is understandable that North Americans pay little heed to stories of wholesale malnutrition in Far Eastern countries. And where farmers are paid by the government to keep land out of production, the word famine—even hunger—loses much of its impact. Only recently, since Canada has reduced her supplies of grain in storage through sales to Russia and

China, are we beginning to understand that there are, in fact, no food surpluses at all.

2 It would be dangerous to delude ourselves that the problems of overpopulation and food shortages can be solved easily. All sorts of alternatives to our present sources have been proposed, among them plankton from the sea, fish meal, and petroleum extracts. However, even if plankton could be made suitable for human consumption, it would still be a poor substitute for bread, while protein extracted from natural gas would provide only one required nutrient. No, we must look to improved farming techniques, soil conservation, and better distribution of water—and greater control of parasities. More insidious than the hordes of insects that chew and munch away a large percentage of the growing crops are the many fungi, bacteria, and viruses that are so stealthy in their work that no accurate estimate has been made of their depredations. So silently do they thrive, both below ground and above, that often only faint discolourations, spottings, wilted leaves, stained roots and tissues—a strange tint here and an unusual shade there—warn the farmer that his crop is sick. Sometimes, indeed, spores of decay bacteria ride the winds right into the warehouses of the wholesaler and the stores of the retailer to spoil food after it has been successfully harvested and processed.

Any serious attack on the problems of poverty and starvation, whether at home or abroad, must recognize plant diseases as one of the major obstacles. Whatever the possibilities for producing food from presently inedible substances, they lie far in the future, and time is running out. Meanwhile, plant pathologists are waging a dramatic battle on a worldwide front against the fungi, the bacteria, and the viruses, enemies whose reserve troops seem inexhaustible, and that destroy about 20 per cent of all the carbohydrates, proteins, and fats that the farmers of the world produce—one fifth of all man's food!

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